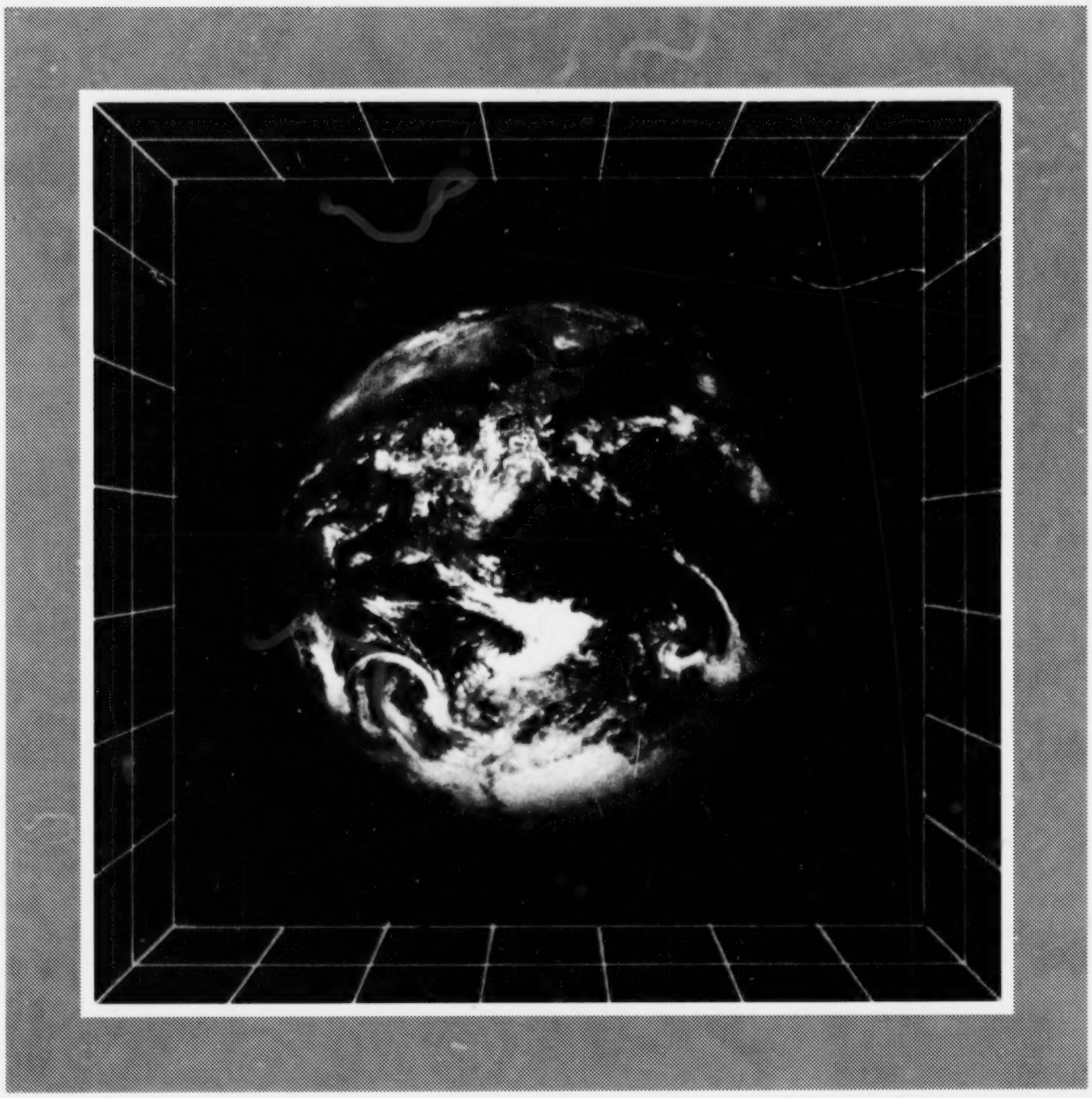
UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

COMBATING GLOBAL WARMING

Study on a global system of tradeable carbon emission entitlements

UNITED NATIONS



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UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT
Geneva

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UNITED NATIONS
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Explanatory notes

The term dollar ($) refers to United States dollars, unless otherwise stated.

The term 'billion' signifies 1,000 million.

The term 'tons' refers to metric tons.

Use of a hyphen (-) between dates representing years, e.g. 1990-1991, signifies the full period involved, including the initial and final years.

An oblique stroke (/) between two years, e.g. 1990/91, signifies a fiscal or crop year.

N.A. indicates that the data are not applicable.

A zero sign (0) indicates that the amount is nil or negligible.

A plus sign (+) before a figure indicates an increase; a minus sign (-) before a figure indicates a decrease.

Details and percentages do not necessarily add up to totals, owing to rounding.

Acronyms

AGDP	adjusted gross domestic product
Btu	British thermal unit
CBOT	Chicago Board of Trade
CEM	continuous emissions monitoring (United States)
CFC	chlorofluorocarbon
CH	clearing house
CME	Chicago Mercantile Exchange
CO2	carbon dioxide
COPE	The CO_2 Offset Policy Efficiency Act (of 1991)
DC	developing country
DMR	discharge monitoring report (under United States Clean Water Act)
EC	European Community
EDF	Environmental Defense Fund
EEC	European Economic Community
EFTA	European Free Trade Area
EPA	Environmental Protection Agency
ERC	emission reduction credit
GEF/WB	Global Environmental Facility/World Bank
GDP	gross domestic product
GHG	greenhouse gas
GNMA	(United States) Government National Mortgage Association (commonly known as Ginnie Mae)
GNP	gross national product
IEA	International Energy Agency
IMM	International Money Market
INC	Intergovernmental Negotiating Committee (on a framework convention on climate change)
IPCC	Intergovernmental Panel on Climate Change
ISDA	International Swap Dealers Association, Inc.
LIFFE	London International Financial Futures Exchange
MATIF	Marché à Terme International de France
NGO	non-governmental organization
NOx	nitrous oxide
NPDES	National Pollutant Discharge Elimination System (under United States Clean Water Act)
NYMEX	New York Mercantile Exchange
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries

R and D	research and development
SIMEX	Singapore International Monetary Exchange
SO2	sulpher dioxide
SWIFT	Society for Worldwide Interbank Financial Telecommunication
TCEE	tradeable carbon emission entitlement
UNCED	United Nations Conference on the Environment and Development
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNGDPA	United Nations Global Environmental Protection Agency
VOC	volatile organic compound

Foreword

Concern with protecting the environment for the benefit of present and future generations is now at the centre of the international agenda. Awareness is steadily growing of the extent of the damage done to our planet's environment through unsustainable patterns of development. In particular there is growing awareness of the need for international action to implement realistic and workable solutions for the reduction of man-made emissions of greenhouse gases that cause global warming. The present study seeks to contribute to international understanding of how that might be accomplished.

When in May 1990, at a high-level gathering on the environment in Bergen, Norway, I proposed that serious consideration be given to the idea of controlling carbon dioxide emissions through a system of "tradeable permits", it was dismissed by some as suggesting an internationally agreed "permission to pollute". It is gratifying to observe that, in the period since then, the notion of "tradeability" and the benefits deriving therefrom, namely, flexibility, the cost-effective control of emissions, and the transfer of environmentally sound technologies and financial resources to poorer countries, have become better understood and appreciated.

This study is designed to elaborate on the ideas first put forward in Bergen, and to outline how an international system of tradeable carbon emission entitlements could work. The proposal has two main aspects: (1) an international market-based instrument for controlling the world-wide growth of carbon emissions at minimum cost; and (2) an effective mechanism for transferring resources (i.e. environmentally sound technologies and finance) to developing countries, to enable them to contribute to the global effort to abate greenhouse emissions without holding back their own development.

A fundamental concern is the right of poor countries to achieve sustainable development and growth. Industrialized countries are responsible for most of the past and current emissions of CO_2 and other greenhouse gases. It is essential to recognize that this constitutes an "environmental debt" to other parts of the world that would need to be taken into account in framing a multilateral agreement on climate change.

This publication is the fruit of a major effort by the UNCTAD secretariat to bring together the experience of experts in both developed and developing countries, academia and private business. Their collaboration was made possible by the generous financial support of the Governments of the Netherlands and Norway.

The launching of this publication is timed to coincide with the convening of the United Nations Conference on Environment and Development (The Earth Summit), to be held in Rio de Janeiro in June 1992. We hope that the Conference will assign to tradeable emission entitlements an important role both in controlling emissions and in financing environmental protection.

K.K.S. Dadzie
Secretary-General of UNCTAD

OVERVIEW

by the Secretary-General of UNCTAD

Global warming and development

The dynamics of global warming

If the earth had no atmosphere, the average temperature on its surface would be well below freezing. Various gases in the earth's atmosphere absorb infrared radiation and act as a blanket which helps trap the heat absorbed through the atmosphere and re-emitted from the earth's surface. Human activity is increasing the concentration of such "greenhouse" gases, and, in the words of the Intergovernmental Panel on Climate Change (IPCC), "these increases will enhance the greenhouse effect, resulting on average in an additional warming of the earth's surface".

The pace and distribution of this disturbance to the earth's climate are subject to considerable uncertainty. The model results used by the IPCC show that present trends would result in a likely increase in global mean temperature of about one degree centigrade above the present value by 2025 and 3 degrees centigrade before the end of the next century. This would be accompanied by an average rate of global mean sea-level rise of about 6 centimetres per decade over the next century. However, the IPCC stated that there were many uncertainties with regard to the timing, magnitude and regional patterns of climate change.

The IPCC was not able to reach clear conclusions about the impacts of prospective changes. Agricultural impacts could be considerable at the regional level, but "studies have not yet conclusively determined whether, on average, the global agricultural potential will increase or decrease. Water resources could be altered, and "relatively small climate changes can cause large water resource problems in many areas ... changes in drought risk represent potentially the most serious impact of climate change on agriculture." Such factors, combined with changes in disease patterns and the impact of sea-level rises combined with storm surges, "could initiate large migrations of people". The IPCC emphasized that a key determinant would be the rate of climate change; whether a warmer world might be better or worse, rapid changes could disrupt both human societies and natural ecosystems.

The policy issues raised by global warming are complex and unique. Not least of the complexities is the need to deal with risk and uncertainty. As the IPCC has put it, "the unequivocal detection of the enhanced greenhouse effect from observations is not likely for a decade or more". And yet "continued emissions of long-lived gases (carbon dioxide, nitrous oxide and the CFCs) at present rates would commit us to increased concentrations for centuries ahead". There is now a widely - though not universally - shared view that when faced with risks which are menacing, and most likely irreversible, uncertainty argues strongly in favour of prudent action and against complacency.

It is assumed in what follows that a significant number of national governments will wish to respond to current risks and uncertainties through prudent action to slow the emission of greenhouse gases.

Development and carbon emissions

Carbon dioxide has been responsible for over half the enhanced greenhouse effect in the past and, according to the IPCC, is likely to retain this role in the future. Carbon dioxide emissions, in turn, are mainly the direct result of the consumption of fossil fuels.

The industrial revolution marked a significant and irreversible change in the nature of economic activity. A key element in this change was the development of steam power, and, later, steam-generated electricity and the internal combustion engine, as sources of power. This, together with standardization of outputs and inputs that accompanied the development of mass production, gave rise to a rapid expansion of industrial, and in particular manufactured, output. There followed rapid increases in labour productivity in the industrial sector; higher and rapidly advancing material standards of living of those engaged in industrial activities; the application of industrial production techniques, especially mechanical power, to the agricultural sector; the migration of labour from agricultural to other activities; and a growing share for industrial output in total economic activity.

This process began in parts of Europe toward the end of the eighteenth century, and during the nineteenth century spread throughout Europe and North America, where it continued into the first half of the twentieth century. One of its main characteristics was continuous success in harnessing fossil fuels to broaden and deepen the production process. The development of the transport sector, and the growing mobility of goods and persons, was a notable aspect of this. Throughout, consumption of fossil fuels rose rapidly, as did carbon emissions.

In the rest of the world, the industrial revolution took hold after the beginning of the twentieth century. In Japan the pace of adaptation, though interrupted by the Second World War, has been particularly rapid, and has carried that country to the forefront of the industrial nations. In other parts of Asia and Latin America, the process generally started later (sometimes much later) and has proceeded at a slower pace. In Africa, the process of industrialization remains nascent.

At the beginning of the 1990s, a large number of the world's economies are still engaged in the process of industrialization that had been by and large completed in Europe and North America by the mid-twentieth century, and in Japan two decades later. Although there is no reason to believe that completion of this process requires other countries to follow step by step the paths established by developed countries, the broad characteristics of the process of development are clear enough: development means industrialization; and industrialization entails the systematic application of controlled mechanical energy to an ever-widening range of productive activities. Although other sources of power undoubtedly have a role to play, a large proportion of this energy must come, in the foreseeable future, from fossil fuels.

The policy conundrum

The dynamics of global warming and the requirements of development appear to be on a collision course. Dealing with the first will require significant abatement of the emission of greenhouse gases, in particular carbon dioxide. But throughout the developing world the need is for continued rapid industrialization (where the dynamics of industrialization have taken hold, as in parts of South-East Asia); a revival of industrialization (where the process has been interrupted, as in parts of Latin America); or the strengthening of an incipient process of industrialization (where the dynamics of industrialization remain weak, as in much of Africa and parts of Asia). All this implies further increases - and over time progressively larger increases - in carbon dioxide emissions. Thus, the imperatives of global warming and of development pull in diametrically opposite directions.

The way out of this conundrum cannot simply be to exempt developing countries from participating in international efforts at emissions abatement, although this might be a reasonable temporary first step (see below). Developing countries account for a growing proportion of global carbon emissions; an international agreement that did not include provision for abatement by them would not be able to achieve over time its objectives. It also needs to be underscored that developing countries themselves have a strong interest in global abatement

and in the methods of achieving it. All of them would be affected by climate change, and, for some, the consequences of drought or a rise in the sea level could be calamitous. Other developing countries are producers of fossil fuels and are necessarily concerned by the implications of global warming, and of the measures undertaken to forestall it, for their earning power. In the longer run, however, their needs are to transform non-reproduceable resources into reproduceable assets. For these countries, too, industrialization is the key to the future, and the impact of measures to deal with climate change will ultimately need to be judged by this criterion.

Rather, the way out of the policy conundrum must be to seek policy approaches that meet three principal criteria. These are:

- That they be capable of bringing about the overall global abatement in emissions required by the collective judgement of the international community, basing itself on available scientific evidence;
- That they allow continued economic development in all countries, and enable the process of industrialization to proceed unimpeded in those countries in which this process is incomplete;
- That they provide appropriate incentives to ensure that industrialization in developing countries, and the replacement, renewal and expansion of industrial facilities in developed and developing countries, embody technology and practices that are emission efficient.

Towards a cross-border allocation of abatement efforts: possible first steps

To date, international efforts at limiting various emissions have centred around the negotiation of national obligations. The Montreal Protocol, UNECE agreements on sulphur and nitrous oxides, and the EC's Large Combustion Plants directive on sulphur emissions all follow this pattern. The use of emissions targets is economically more efficient than procedural requirements that specify technical control mechanisms (such as mandated levels of energy efficiency or the use of scrubbing techniques). However, an agreement based on equal percentage reductions for each participating country would none the less be relatively inefficient. This is because there are wide variations among countries in the costs of abatement, reflecting a variety of factors - including the extent and intensity of abatement efforts undertaken prior to the agreement. Some countries would thus incur substantial costs in achieving relatively modest percentage reductions, while others could reduce emissions by much more at less cost. If all countries were bound to equal proportionate reduction targets, many relatively cost-effective options for reducing emissions could go unexploited. Moreover, countries in which costs of abatement are relatively high would have an keen interest in limiting the percentage reduction figures embodied in the agreement and/or securing special dispensations for themselves. International agreements negotiated within this framework are thus likely to be unusually difficult to negotiate (in so far as they require explicit recognition of individual country situations); unfair (in so far as they impose burdens of different relative magnitudes on the participants); economically inefficient (in so far as the marginal costs of abatement remain distinctly different among the participants in the agreement); and involve less abatement than might otherwise be possible.

Considerable attention has therefore been directed towards mechanisms that would increase the flexibility of international agreements, so as to allow each participating country greater latitude in seeking out the lowest-cost means for meeting its abatement obligations. One way of doing this would be to allow a participating country to earn credit towards its own abatement obligation by financing abatement in another country - whether or not the second country is a participant to the agreement. Such action - called an offset - would be undertaken when it reduces the costs of compliance.

A plausible scenario for an initial attempt to reach an international agreement to limit carbon emissions would be to build on actions that countries have already taken. In such a scenario, a group of countries in a position to do so would each undertake a commitment with regard to the level of its own emissions. This group would, at least initially, be relatively small, and may not include any developing country. Each participating country would, of course, seek out within its own national borders the least cost means of meeting its commitments. But it would also be enabled to seek out investments in other countries that allow reductions in global emissions at lower cost than is possible within its own national boundaries. Such offsets would then be credited to the participating country, and the reduction of emissions in the other country would be counted as part of its effort to meet its own emission target.

In order to function properly, a system of international offsets would need an international agency to facilitate and oversee its operations. This agency would need to undertake a number of functions including:

- The monitoring of emissions in countries participating directly (i.e. signatory countries) or indirectly (i.e. countries where offset investments are taking place). As regards offsets, all parties involved would have to submit to the agency detailed information on the investment in question and would have to quantify credibly the impact on global emissions of the investment project over its entire lifespan. The role of the agency would be particularly important when the investment is made in a third (i.e. non-signatory) country that does not have elaborate national control and monitoring systems;
- A recording system for transfers of credit emanating from offsets;
- A credible enforcement mechanism to ensure compliance.

The agency may also undertake to foster offsets, for example, by disseminating information on potential offset investments to interested parties.

Such a system of international offsets could play an important role in augmenting the efficiency - and therefore the political acceptability - of an international agreement based on national quotas. It would also familiarize the international community with operations involving cross-border transactions in emissions, and would introduce an instrument that could readily be adopted and utilized no matter how international understandings on emission abatement were to evolve. Such a system would also help developing countries secure financing for additional emission-efficient investment, an important ingredient in their own sustainable development.

As with any international scheme to control emissions, there are a number of difficulties that would have to be overcome to make such a scheme fully credible. One of the more important of these is the problem of determining when an investment presented for an offset represents a genuine addition to international abatement efforts. There may also be questions as to whether such a scheme, as useful a first step as it is, could long serve without further evolution. The limited participation postulated, while an advantage in allowing for relatively rapid agreement on an international scheme, will work against the objectives of the scheme in the longer run, as important and growing sources of emission are seen to lie outside the reach of the agreement. In particular, developing countries would have little incentive to join such an agreement, and the temptation to be a "free rider", i.e. a country that benefits from global action but does not participate in it, would always be present. In the longer run, what is needed is an approach that provides important direct and indirect benefits to all countries. This requires directly confronting the issue of how to reconcile the imperative of climate control with the imperative of acclerated development.

The case for tradeable emission entitlements

Any search for a control mechanism that could be used in a broad-based international agreement to limit greenhouse gas emissions must give high priority to the need to achieve such a limitation at the lowest possible economic cost. This means the identification and ex-

ploitation of the cheapest opportunities for abating emissions in the countries participating in the agreement. Yet, there is no way that those actually negotiating such an agreement can be in possession of the information required to make such an identification; indeed, countries are likely to have to enter such an agreement with only approximate information on what their own marginal costs of abatement are likely to be, and even less idea of how these costs might evolve during the life of the agreement. A successful control mechanism must therefore hold out the prospect that least-cost solutions to abatement objectives will be found, even when information on costs available to regulators is incomplete, and must also provide governments with flexibility in meeting their objectives.

Transferable entitlement systems meet these criteria. Under such a system, entitlements allowing emissions of a certain magnitude are created and distributed to the economic actors involved. The trading of entitlements among participants would be allowed. An actor that finds himself with entitlements to less emission than is currently occurring in the area under his jurisdiction has two options. He can bring himself into conformity by cutting back on emissions until they correspond to the entitlements in his possesion, bearing whatever costs that process entails. Or, he can purchase (or rent) additional entitlements from other participants, bearing whatever cost the market demands. Clearly, the actor will purchase (or rent) entitlements only if that is less costly than the cheapest way available to him of reducing emissions. Likewise, the participant offering the entitlement for sale will require a price for the entitlement that exceeds the costs of producing a saleable entitlement - i.e. that exceeds the costs of abatement in his territory. Thus, a tradeable entitlements system produces any given level of global abatement at least cost, even though no single participant in the system is in a position to know, or evaluate the cost, of all opportunities for abatement.

In addition to being cost-effective in the short term, a tradeable entitlements system will encourage more technological progress in emissions control than would a system involving fixed targets or standards. This is because actors have an incentive to develop and apply technologies even when they are in compliance with the standard, since further abatement of emissions would give rise to "saleable" entitlements that would generate income for the technology owner.

Experience at the national level with tradeable emission entitlements has demonstrated that the cost savings of such a system as compared with traditional regulatory approaches can be quite large: in the United States most estimates put the savings achieved by allowing emissions trading under the Clean Air Act at over $10 billion. National experience also shows that considerable savings can be achieved even when the trading area and potential trades are rather small (although, of course, the gains increase the larger the area and number of potential trades). Experience also indicates that such a system has considerable flexibility, that it can be useful even when the number of participants and/or emissions covered is limited, and can evolve easily into a more comprehensive system. A full blown, comprehensive international agreement would therefore not be necessary from the outset to achieve environmental and cost-effective goals.

The most telling feature of emission entitlement systems, however, is that, assuming the market for entitlements is competitive, the advantages described above can be secured in full whatever the initial distribution of entitlements. This is a significant characteristic, because it provides a means for tackling the development dimension of emission abatement in the context of a fully cost-effective system.

The initial allocation among governments of emission entitlements could be undertaken in a way that would endow developing countries with more entitlements than required by present and prospective emissions, and developed countries with fewer entitlements than required by present emissions. In addition to providing cost-effective abatement, such a distribution would:

- Provide developing countries with "room" to expand emissions of greenhouse gases as required by their on-going industrialization;
- Allow developing countries to sell or rent entitlements they do not presently require, thereby generating a flow of foreign exchange that could be used to finance emission-efficient investment;

- Provide policy makers in developing countries with a set of incentives that ensures that their industrialization process proceeds in a way that minimizes emissions. It is only through ensuring emission efficiency that a developing country could protect the source of income represented by the excess of entitlements over actual emissions.

It should also be noted that the distribution pattern spelled out above would make "free riding" quite costly, and would reduce appreciably any tendency for emission-intensive industries to be relocated from developed to developing countries.

In search of distribution criteria

The finding that the initial distribution of emission entitlements can be used to reconcile the need for global abatement of greenhouse gases with the need for further industrialization in developing countries is an important one. But it does not answer the question of whether there is a distribution pattern that will bring about this reconciliation in a way that produces net benefits for all countries entering into an international agreement. This issue is central to the case for using tradeable entitlements as an international control mechanism.

There are two possible approaches to exploring this issue. One approach would address frontally the question of fairness or equity as it relates to distribution, and explore whether some distribution patterns that flow from this concern also generate net benefits to all participants. A second would seek out in the first instance distribution criteria that produce net benefits for all participants, and then examine the equity implications of these criteria. Both approaches merit pursuit, and when, as will be seen shortly, the conclusions reached by the two strains of analysis are similar, confidence in the outcome is enhanced.

Fairness, or equity, has to be seen against the background of both differences among countries in present income levels and the development and industrialization imperative mentioned above. Both mean that monies spent today by developing countries on abatement, rather than on investment for expanding future output and material well-being, have a relatively higher cost in developing than in developed countries. Fairness also requires explicit recognition of the dynamics of world industrialization, referred to above, which has produced dangerous levels of carbon emissions for the world as a whole while providing the material benefits of industrialization to only a part of the world's population.

A number of different concepts of fairness or equity are relevant to a discussion of criteria for the initial distribution of entitlements. One such concept would be that each individual inhabiting the earth has the same rights and responsibilities vis-à-vis the earth's atmosphere as any other. This "egalitarian" concept of fairness would suggest that emission abatement should be undertaken in proportion to population, and that entitlements should be allocated also in proportion to population. Other concepts would view equity as having been achieved if the net cost of abatement as a proportion of GDP were the same for all countries ("horizontal equity") and would seek an allocation formula for entitlements that produced this outcome. A further concept of equity ("vertical equity") would allocate progressively higher costs (in terms of GDP) to wealthy countries, and would devise an allocation formula that produced that outcome.

Another important concept is the rule of compensation, which states that a policy should be pursued as long as those who gain from the policy can compensate those who lose, and can do so to an extent that allows both winners and losers to be better off than if the policy had not been adopted.

These concepts of equity can be applied using a variety of indices against which to gauge the equity implications of various policy designs - including population, land area, energy use, and economic welfare. Of considerable interest are indices that take account of cumulative emissions, and those that explicitly seek to take account of the effects of present abatement on the future growth and development of developing countries. Using a set of rough, stylized facts to capture the likely costs and benefits of abatement in different countries and regions, one can explore the likely implications of applying different equity criteria to the indices that are relevant to them. When the concept of compensation is applied to indices that reflect cu-

mulative emissions and future development needs, a pattern of entitlement distribution can be found that produces considerable gains for developing countries, clear gains for some industrial countries, and losses for no one. While such an exercise has limitations (see below) it does suggest strongly that distribution criteria can be found that meet the requirements spelled out at the outset.

A different way of approaching the search for distribution criteria is to seek out criteria that produce gains for all participants (as compared to a situation in which there is no international agreement) and then examine the equity properties of the criteria that meet this objective.

In this approach the analysis begins with an examination of a number of allocation rules that have been suggested by other studies. Rules that apply the same way to all countries (uniform allocation rules) do not pass the test of providing gains to all participants, although some perform better than others. Indeed, some of these uniform rules, such as equal entitlements per capita, polarize negotiations by substantially favouring one party over another. Rules that are constructed by combining uniform rules perform better. For example, a rule based on a weighted average of emissions per capita and equal percentage abatement could meet the objective of providing gains for all in circumstances in which the cost of global warming is assumed to be high. The reason this rule has limited success is that it favours the "average" country, at the expense of countries with more extreme values for emissions per capita.

An alternative approach would be to allocate entitlements according to two different rules, each being applied to a different group of countries. The two-tier allocation rule - in particular a rule that imposes a different obligation on poor countries than on industrialized countries - has some advantages but fails to provide gains for countries that are neither poor nor industrialized, but somewhere in between.

A final rule that was evaluated is the "Kantian rule", which requires each country to choose an abatement level that is at least as large as the uniform abatement level it would like all countries to undertake. This rule meets the objective of making all countries better off compared with a situation in which there is no international agreement, and provides sizeable gains to developing countries. The reason this rule works well is that it allows obligations to vary across countries, and recognizes that some countries have a greater preference for abatement than others. This outcome suggests that there is a family of solutions characterized by multi-tier abatement requiring greater abatement by countries that would benefit more from emission limitations. Since the major industrial countries are likely to benefit most from abatement, they should bear the greater burden of emissions reduction in the initial allocations of entitlements. However, trading entitlements will reduce their cost burden, and the transfer of resources to the poor countries will provide these countries with an incentive to accede to the agreement, proceed with their own industrialization and abate their emissions.

The conclusion that emerges from the above is that whether one approaches the search for an allocation rule primarily from the standpoint of equity or primarily from that of mutual acceptability, distribution rules that meet both objectives can be found. This conclusion, to be sure, needs to be reinforced by further analysis involving a larger number of specific country situations as well as the generation and deployment of more detailed data. Nevertheless, it represents a significant step forward in clarifying the way in which tradeable entitlements could be used in an international agreement to abate greenhouse gases.

Implementation issues

There is no precedent for cross-border trading in greenhouse gas entitlements. The design and implementation of a global system of tradeable carbon emission entitlements is, in consequence, an innovative endeavour. Basic design requirements and some obvious potential problems such as the risks of cartelization and hoarding, adjusting the supply of entitlements, and the technical requirements for monitoring and enforcement will be posed by negotiators from the outset. Other important problems will certainly arise as the system

evolves, and all will require detailed examination. The following paragraphs describe briefly some of the principal issues that will have to be addressed.

Key design issues

In theory, a comprehensive approach incorporating all greenhouse gases, their sources and sinks, allows the global warming objective to be achieved with the widest selection of options. However, because of information problems, incorporating all such sources from the beginning would run the significant risk that fraudulent trades could result - trades that appear to involve equivalent reductions in greenhouse gases, but in fact do not. However, starting with a system based on carbon dioxide from fossil fuels, which is relatively easy to monitor and document, would not preclude its subsequent expansion to include other greenhouse gases.

Entitlements can be imposed at any stage in the cycle of energy use producing a greenhouse gas, i.e. extraction, production, consumption or emission. All other things being equal, entitlements defined in terms of emissions would be preferred as this would produce the most cost-effective outcome. The tendency of the market to seek the least-cost means of control would be focused on reducing emissions, which, of course, is the objective.

Adjustments in the supply of entitlements, for whatever reason, should not undermine the goal of global warming abatement. One possible source of entitlement supply is provided by participants who undertake activities that absorb or destroy greenhouse gases. Generally, only offsetting activities that go beyound some prespecified baseline should qualify for entitlements.

Facilities for clearing and banking of entitlements are essential requirements, providing a centralized location for transactions and a safe haven for certified but unused credits. Secured banking facilities provide incentives to invest in the activities that release entitlements for cross-border exchange.

Special design problems

- ***Market power*** can exist on either the buyer's or seller's side. The evidence suggests that market power is not likely to pose a serious problem in a global entitlements market. Successful cartels are difficult to establish and maintain for any commodity, and greenhouse gas entitlements would not be an exception. Cartelization is unlikely where the initial allocation of entitlements and the market participants[1] are defined in such a way as to create a large number of buyers and sellers. In addition, new entitlements could be created by the certified destruction or absorption of greenhouse gases. The ultimate protection against the accumulation of market power is the possibility open to all nations to withdraw from the agreement.

- ***Hoarding*** is a response to price and supply risks. In a vigorous global market with large numbers of buyers and sellers and a flexible supply strategy, the preconditions for hoarding would be greatly undermined. In addition, organized markets for futures contracts would enable purchasers to lock in the future price and availability of entitlements, thus further reducing the need to hoard entitlements.

Monitoring and enforcement

Monitoring and enforcement would need to be pursued at both the national and international levels. National authorities would have the major responsibility for monitoring and enforcing the activities of sources within their borders. A designated international organization,

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1 A tradeable entitlement system could be designed in which all trades take place exclusively between governments, exclusively between private parties, or with some mix of the two.

possibly within the United Nations system, would have responsibility for (1) receiving and reviewing monitoring reports from, and issuing compliance assessment reports for, the signatory nations, (2) maintaining an up-to-date accounting system of national obligations and achievements, including changes occasioned by trading, (3) management of a greenhouse gas entitlement bank, and (4) providing technical assistance to participating countries.

The international monitoring agency would have two main sanctions at its disposal: adverse publicity, and veto power over international entitlement transactions.

Efficient markets

Throughout history, markets that function well have had several common features. First, the tradeable commodity was clearly defined, then the "spot" market was established, from which forward, futures and options markets evolved. A successful spot market in CO_2 entitlements requires the issuance of a stock of standard instruments corresponding to the target emissions level. Though the global market might be overseen by an international environmental protection body, which could be within the United Nations system, experienced private sector exchanges offer efficient structures for trading. These exchanges provide international linkages, workable trading rules, reporting and regulatory requirements, trade clearing and financial integrity that would benefit the global entitlements market. The technologies associated with the functioning of private sector exchanges, located mostly in developed countries, could be shared with developing countries that may wish to develop local spot markets in CO_2 entitlements.

. . .

Recognizing the issues discussed above, negotiations on a global Framework Convention on Climate Change started in February 1991 under the auspices of the United Nations General Assembly. This convention, due to be signed at the United Nations Conference on Environment and Development (UNCED) in June 1992, is expected to establish initial measures and the structure and principles on which subsequent protocols to the convention will be based. The convention itself may include some preliminary commitments, and will do much to define the options for subsequent negotiations on the limitation of emissions. An effective global system of control is unlikely to be created in one step, and it is therefore important that the framework convention establish a context that allows subsequent protocol negotiations to consider the best options for structuring an evolving system to address the threat of climate change. Tradeable emission entitlements will surely figure prominently among those options.

K.K.S. Dadzie

Chapter I

INTRODUCTION: NATURE OF THE ISSUE AND POLICY OPTIONS

Michael Grubb and Adam Rose*

Summary

Climate change poses unique problems for the global community of nations. We know that emissions of CO_2 and other gases are changing the heat balance in the lower atmosphere, and that this is likely to lead to surface warming and associated climatic changes, but the likely impacts are still very uncertain in detail, especially for regional changes. Yet the consequences could be extremely serious, and by the time the evidence is clear it will be far too late to prevent much further change. Humanity can adapt to some climatic change (and will have to, regardless of abatement efforts, because of past emissions), and it may be possible to absorb some greenhouse gases from the atmosphere, for example by reforestation. But the problem seems too great to rely exclusively on such methods, and there is therefore a growing recognition that emissions need to be limited.

But many of the important greenhouse emissions - CO_2 from fossil fuels and from deforestation, and methane from agriculture - are intimately associated with basic energy and agricultural development, so the costs and political difficulty of limiting them could be onerous. Many countries contribute, but they differ radically in their past and current contributions, and in the ease with which they can limit future emissions. Emissions from developing countries form under a half of total greenhouse gas emissions, and only a quarter of fossil CO_2 emissions, but they are growing rapidly, so that a global agreement would be required.

However, developing countries are concerned that abatement efforts could damage their development and feel that they should not pay for a problem largely caused by the industrialized world, whereas developed countries are concerned about bearing the full long-term cost, and whether the funds provided would be efficiently used. Moreover, it is extremely difficult to determine exactly how much abatement efforts would cost, and how they can best be implemented, while any agreement reached must last for a long time if it is to be effective. All these factors show clearly that an agreement is necessary, but that it will be very complex to work out and must be framed with great care.

* The Royal Institute of International Affairs, London, and the Department of Mineral Economics, The Pennsylvania State University, PA, respectively.

A. Reasons for concern

If the earth had no atmosphere, the average temperature at the surface would be well below freezing. Various gases in the atmosphere absorb infra-red radiation and act as a blanket which helps to trap the heat absorbed and re-emitted from the surface. Human activity is increasing the concentration of such radiatively active "greenhouse gases", and hence changing the radiative balance in a way that seems certain to increase the surface temperature.

The rate and extent of temperature rise, and its implications, are a matter of considerable uncertainty. A rise in temperature increases the concentration of water vapour in the atmosphere - itself the most important greenhouse gas - and changes the extent and nature of clouds, snow fall and ice cover; these and many other feedbacks, together with the uncertain role of oceans, greatly complicate assessment of temperature and related climatic changes.

It is not yet clear whether human interference with the atmosphere has pushed the temperature beyond the considerable range of natural variability. However, the 1980s saw the six warmest years on record and some extreme climatic disturbances - the most important of which politically was the drought of 1988 in the United States - and this helped to establish the greenhouse effect as a major political issue.

In response to widespread concerns, and the results of a series of international scientific workshops, the Intergovernmental Panel on Climate Change (IPCC) was established in 1988. Charged with conducting an international assessment programme, the IPCC produced its first report in the summer of 1990. The conclusions of Working Group I (Science) (summarized in the following box) supported the growing scientific concerns. The basic theory that increasing concentrations of greenhouse gases will tend to warm the planet's surface is unchallengeable. Also, the world has warmed in the last 100 years, and especially since the late 1970s. Natural variability and other factors mean that this cannot conclusively be attributed to the greenhouse effect, but it is consistent with current understanding of it. If trends in emissions continue as projected, global average surface temperature over the next century is likely to rise by several (1.5-4.5) degrees centigrade (compared with about 4.5 degrees difference between the present and the depth of the last ice age some 20,000 years ago). The changes would not be smooth and there would be considerable regional variations in both temperature and other impacts, most notably rainfall and soil moisture. Storm patterns might change, and sea levels rise.

Naturally not everyone has accepted the conclusions of the IPCC first assessment. A few scientists argued that the likely rate of change was considerably smaller than the IPCC suggested, and that the IPCC report was unduly pessimistic. Others expressed the fear that the conclusions were dangerously cautious and highlighted the possibility of further feedbacks which would amplify the concentrations of greenhouse gases. The IPCC report itself noted that "it appears likely that, as climate warms, these feedbacks will lead to an overall increase, rather than decrease, in natural greenhouse gas abundances. For this reason, climate change is likely to be greater than the estimates we have given."

The IPCC Working Group II (Impacts) found that, given the uncertainties concerning precipitation and other regional variations, it was not possible to reach clear conclusions about the impacts. Climate change would be combined with other environmental stresses caused by human activities and natural variations. Agricultural impacts could be considerable at the regional level, but "studies have not yet conclusively determined whether, on average, the global agricultural potential will increase or decrease". Natural ecosystems, both on land and and in the oceans, would be altered. Water resources could be a particular concern because "relatively small climate changes can cause large water resource problems in many areas ... change in drought risk represents potentially the most serious impact of climate change on agriculture". Such factors, together with changes in disease patterns and the impact of sea level rises combined with storm surges, "could initiate large migrations of people". Overall, the Impacts report emphasized that a key determinant would be the

SUMMARY OF THE CONCLUSIONS OF THE IPCC WORKING GROUP I ON SCIENCE

We are certain of the following:

- There is a natural greenhouse effect which already keeps the earth warmer than it would other wise be.
- Emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases (carbon dioxide. methane. chlorofluorocarbons (CFCs) and nitrous oxide). These increases will enhance the greenhouse effect. resulting on average in an additional warming of the earth's surface.

We calculate with confidence that:

- Carbon dioxide has been responsible for over half of the enhanced greenhouse effect in the past, and is likely to remain so in the future.
- Atmospheric concentrations of the long-lived gases (carbon dioxide, nitrous oxide and the CFCs) adjust only slowly to changes in emissions. Continued emissions of these gases at present rates would commit us to increased concentrations for centuries ahead.
- The long-lived gases would require immediate reductions in the net emissions from human activities of over 60 per cent to stabilize their concentrations at today's levels: methane would require a 15-20 per cent reduction.

Based on current model results, we predict:

- The IPCC Business-as-Usual (Scenario A) emissions of greenhouse gases ... will result in a likely increase in the global mean temperature of about 1°C above the present value by 2025 and 3°C before the end of the next century.
- That land surfaces warm more rapidly than the oceans. and higher northern latitudes warm more than the global mean in winter.
- Regional climate changes differ from the global mean, although our confidence in the prediction of the detail of regional changes is low. For example, temperature increases in Southern Europe and central North America are predicted to be higher than the global mean, accompanied on average by reduced summer precipitation and soil moisture.
- An average rate of global mean sea-level rise of about 6 cm per decade over the next century.

There are many uncertainties in our predictions particularly with regard to the timing. magnitude and regional patterns of climate change .

Our judgement is that:

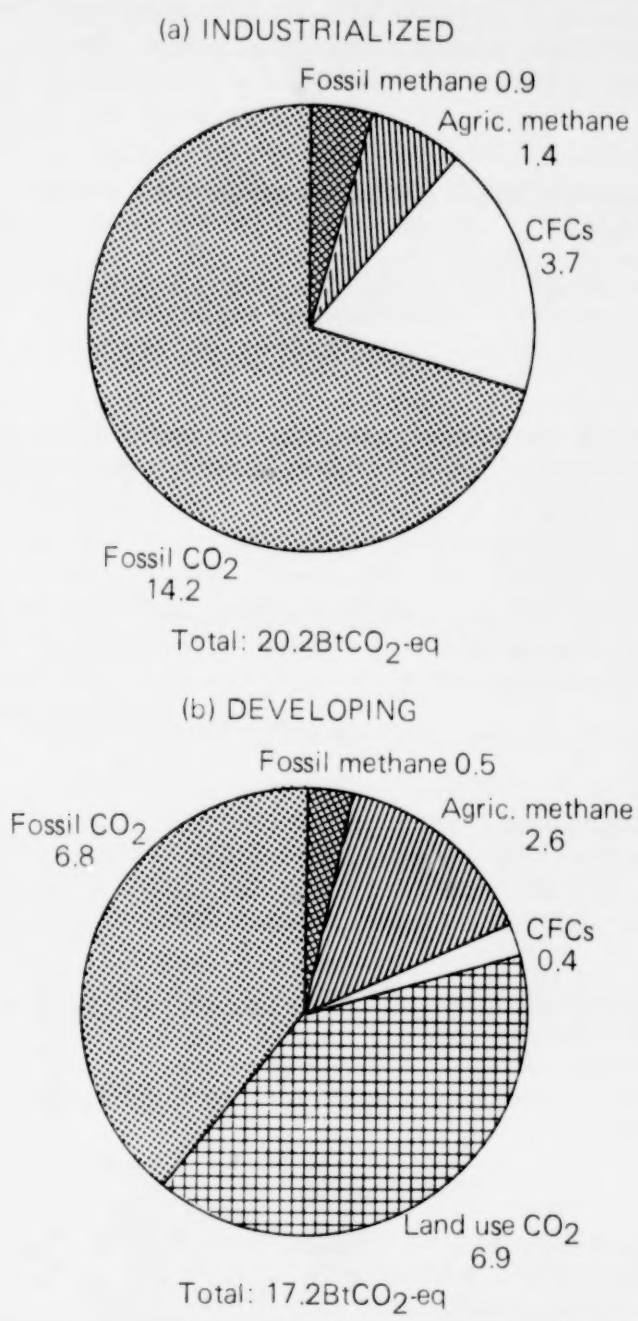
- Global mean surface air temperature has increased by 0.3°C to 0.6°C over the last 100 years, with the five global average warmest years being in the 1980s ... These increases have not been smooth in time, nor uniform over the globe.
- The size of this warming is broadly consistent with predictions of climate models, but it is also of the same magnitude as natural climate variability.
- The unequivocal detection of the enhanced greenhouse effect from observations is not likely for a decade or more.
- There is no firm evidence that climate has become more variable over the last few decades.
- Ecosystems affect climate, and will be affected by a changing climate and increasing carbon dioxide concentrations.

Note: The 1992 Update of the IPCC Studies reported that "Findings of research since 1990 do not affect our fundamental understanding of the science of the greenhouse effect and either confirm or do not justify alteration of the major conclusions of the first IPCC Scientific Assessment".

rate of climate change; irrespective of whether a stable warmer world might be better or worse, rapid changes could disrupt both human societies and natural ecosystems.

Figure 1

CONTRIBUTION OF DIFFERENT GASES TO RADIATIVE CHANGE DURING THE 1980s

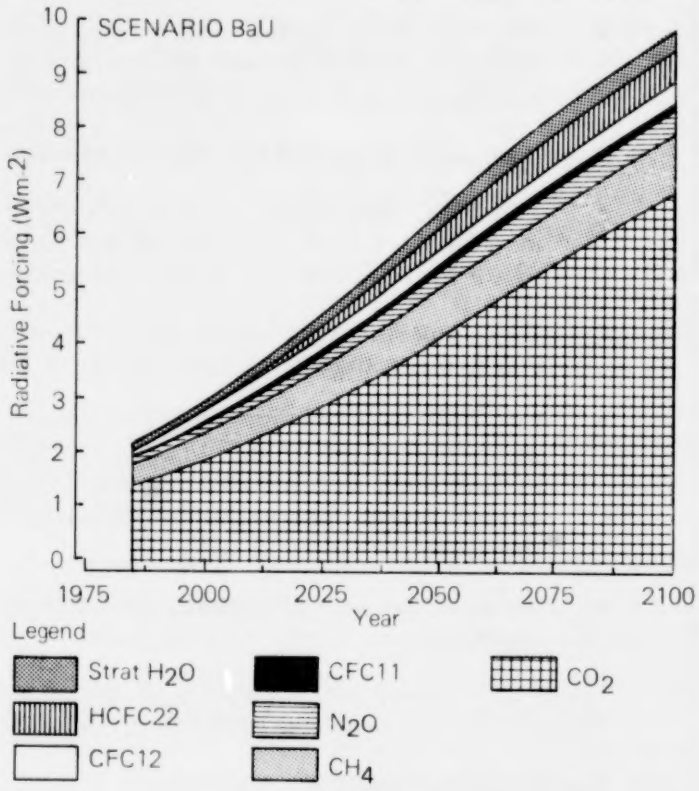


Source: Derived by the authors from data in World Resources Institute, *World Resources 1990-91*, corrected for more revised estimates of deforestation rates.

Various different gases contribute to the projected changes. The biggest single contributor is carbon dioxide (CO_2), but CFCs and methane are also important, and there are smaller contributions from nitrous oxide and tropospheric ozone, which is created from a range of other human emissions. Figure 1 shows the contribution of different gases to radiative change in the 1980s, during which CO_2 emissions accounted for about 55 per cent of the total. Because CFCs are being phased out under the Montreal Protocol and subsequent amendments, and CO_2 emissions from fossil fuel use are projected to continue rapid growth, CO_2 is still more central in projected future contributions. Figure 2 shows the IPCC's projected contributions to radiative change over the twenty-first century in a "business-as-usual" scenario.[1]

Figure 2

PROJECTED CONTRIBUTIONS TO RADIATIVE CHANGE OVER THE TWENTY-FIRST CENTURY IN IPCC "BUSINESS-AS-USUAL" SCENARIO, W/m$_2$



Source: *Climate Change: The IPCC Scientific Assessment Report to the IPCC from Working Group I* (Cambridge University Press: Cambridge, UK, 1990).

Most of the climate modelling assessments performed to date have examined the possible consequences of atmospheric change equivalent to doubling the pre-industrial CO_2 concentration in the atmosphere. It is sobering to note that, if emissions continue to grow as projected, this level will

1 Since the IPCC 1990 report, the role of CFCs has been recalculated to include indirect impacts arising from CFC-induced chemical reactions in the atmosphere. This suggests that the net radiative impact may be less than previously believed, slightly reducing the overall projected magnitude of radiative change, but further enhancing the relative role of non-CFC gases.

be reached within about 40-50 years, with continuing and accelerating changes beyond this. Indeed, this level could be avoided only by substantial cuts in projected global emissions, especially of net CO_2 emissions, contrasting with the current growth trend of around 2 per cent per year. A range of different scenarios are possible, but most "business-as-usual" projections point to a doubling of CO_2 equivalent concentrations by the middle of the next century, and to the central role of CO_2 emissions in this. Cuts of 60-80 per cent from current levels of CO_2 and other long-lived gases (CFCs and nitrous oxide) would be required to stabilize their concentration in the atmosphere.

B. Overview of response options

The policy issues raised by global warming are complex and unique. It is a problem requiring responses while the outcome is still very uncertain. The projected climatic changes outlined above are far from certain in any degree of detail, especially at the regional level. The changes could be less damaging than many fear. On the other hand, in changing the planet without fully understanding the consequences, humanity is clearly running a degree of risk that the changes could be worse, perhaps with potential surprises in the way the planet responds. Uncertainty itself rarely justifies inaction, and as McCracken (1991) has observed, "we have only one planet and many of the actions are reversible only over centuries or longer, so caution is certainly an appropriate response". Doing nothing is a very risky strategy.

Nor does it seem wise to wait for observational certainty. The extent of natural variations, the buffering effect of the oceans, and the inertia in human systems responsible for the emissions mean that, by the time we can measure for sure how the climate system is responding to increasing greenhouse gas concentrations, it will be too late to prevent many decades of further and more rapid change thereafter.

The three broad options in responding to this situation are adaptation, climate engineering and abatement. ***Adaptation*** strategies focus on accepting climate changes and seeking to minimize the damage involved by adapting to them, both as they come and by measures taken in advance. Mechanisms include migration, development of drought-resistant plant strains, construction of sea defences, etc. Because the changes are uncertain, the emphasis would be on resilience and flexibility. People would have to become reconciled to warming and changing conditions. There could well be benefits in cold areas such as Alaska and Siberia, but changes might be particularly difficult to accommodate in countries that are already hot - many of which are also poor and account for the great majority of the world's population. The international ramifications and stresses of such changes could be considerable.

Difficulties therefore include uncertainties about the overall cost and feasibility of relying wholly on adaptation, the widely differing impacts and ability to adapt between different countries, and the risk of large-scale surprises in the climate system. The danger of unexpectedly high levels of warming or other unexpected changes, when it is too late to stop them, poses another problem. However, it is clear that some adaptation will anyway be required, and the question is more the extent to which it should be relied upon relative to other options.

Climate engineering entails measures intended to offset directly the warming in the lower atmosphere. Examples include altering the reflectivity of the earth's surface, enhancing the cooling effects of water circulation, and screening the earth's atmosphere from the sun's rays. Preliminary estimates of the costs of these alternatives are low. Their feasibility and their unknown and potentially damaging side effects, however, together with the political difficulties of assigning responsibility for such deliberate intervention with planetary systems and any unforeseen consequences thereof, require that they be given only secondary consideration at this time.

Abatement refers to measures that moderate the growth of concentration of greenhouse gases in the atmosphere. ***Sink enhancement*** increases the rate at which greenhouse gases are re-absorbed; the main example is reforestation, though some other

possibilities have been explored. ***Emissions abatement*** refers to preventing emissions of GHGs at source. These measures include phasing out chlorofluorocarbons, increasing energy efficiency, switching to fuels that generate relatively lower levels of GHGs or none at all, reducing methane leaks and deforestation rates, and "scrubbing" the CO_2 out during fossil fuel combustion for disposal probably in depleted gas fields or deep ocean. Thus a wide variety of cleaner technologies need to be used to abate emissions.

These options are not mutually exclusive. Some adaptation will be required irrespective of abatement measures, and climate engineering might prove essential as an emergency response if dangerous degrees of positive feedback do emerge. Sink enhancement could undoubtedly contribute, though all options considered to date are limited by land area, environmental impact and nutrient availability. But to reduce the costs and risks of the continued and accelerating pace of atmospheric change, emissions abatement must also play a role. To achieve goals of environmental protection and sustainable development, the current trend of rising emissions needs to be reversed to limit warming to acceptable levels, and emissions must eventually be reduced to a level at which atmospheric concentrations are stabilized.

Abatement measures need to be considered as comprehensively as possible, so as to include all important sources and sinks of GHGs as far as practicable. At present, however, uncertainties concerning the role and magnitude of many of the lesser sources and sinks, difficulties in monitoring them, and problems in consistently comparing the different gases, make it difficult or impossible to include them in an overall quantified emissions agreement. Thus, different approaches may initially be required for agreements on different sources and sinks according to their characteristics, though it would be desirable for measures to become more comprehensive over time.

Negotiating an agreement on abatement to include fossil CO_2 emissions has to be a central component because they are the biggest single contributor, and it would be relatively easy technically as reliable statistics are readily available and fossil carbon can be fairly easily monitored. But because such an agreement would engage the major economic issues involved in energy supply it would be politically very difficult, and raises starkly the issues of equity, efficiency and distribution in responding to climate change. For these reasons, this study concentrates centrally upon options for an agreement on limiting fossil CO_2, but it does address as far as possible the issues raised by expanding such a system to include other sources and sinks.

C. Uniqueness of the policy issues

Limiting the build-up of greenhouse gases will not be like any other environmental issue. Beyond the phasing out of CFCs, many of the sources of greenhouse gases are closely linked to basic human activities of agriculture and industrialization. There may be options for reducing leakage of methane and other non-CO_2 gases from fossil fuel systems, and for some other "end of pipe" fixes. But substantial steps would have major implications for some of the world's largest industries, and for land use policies especially in developing countries. They could affect trade flows, and alter patterns of economic development.

This is particularly the case for fossil fuel CO_2 emissions, which form the bulk of projected future radiative change. Energy supplies constitute some of the biggest business in the world. Gross annual revenues in the OECD oil companies alone average several hundreds of billions of dollars, bigger than the GNP of many countries. Projected requirements for expenditure on electricity systems in developing countries during the 1990s have been put at about a trillion dollars. In most countries, energy accounts for a considerable percentage of GNP and is a major employer.

At present there is considerable debate about the technical options for limiting CO_2 emissions, and the macroeconomic costs of doing so, especially in industrialized countries. But, however small or large the macroeconomic costs involved, the institutional, social and political obstacles to forcing a decline in the scale of fossil fuel industries in the industrialized world are formidable.

The stakes could be much higher still for most developing countries. Poor countries may be worst hit by climatic change, but

many projections suggest rapidly growing use of fossil fuels in their development. Currently, developing countries as a whole contribute less than 45 per cent of total greenhouse gas emissions on a carbon-equivalent basis, while accounting for nearly four-fifths of the global population. Their low income makes it relatively difficult for them to undertake abatement, but their relative contribution is growing steadily, and may exceed 55-60 per cent by the middle of the next century. Despite the interim economic growth many of these countries may still have only limited means to address the problem; indeed their economic situation relative to today's industrialized countries may not be any better.

Growing attention to the contribution of developing countries to global warming (e.g. Schelling, 1991; World Resources Institute, 1990) is however branded by some (Agarwal and Narain, 1991) as "environmental colonialism". They point to the relatively small per capita contribution of greenhouse gas emissions from the developing world as reflecting a parsimonious use of resources, and point out that if the natural global "sinks" of greenhouse gases were distributed on a per capita basis, emissions from many developing countries would be within the earth's carrying capacity. They argue that warming may be a global problem in terms of effect, but not with respect to cause.

Furthermore, since many greenhouse gases are retained in the atmosphere over long periods, past emissions are relevant to the current and future state of the atmosphere. If one looks at cumulative emissions to date, the developing country contribution is even smaller (Subak and Clark, 1990). It is not surprising that representatives of these countries are critical of most greenhouse warming policies that ignore this consideration. They are quick to point out that the industrialized countries developed without diverting resources into pollution abatement; and ask why developing countries should be asked to forsake some of their future progress for this purpose.

But given their large and growing population and fast growing economies, developing country emissions could increase rapidly, especially given the reliance of some upon soft coal as the fuel of basic industrialization. This, combined with the great scarcity of capital and technical expertise for deploying new and perhaps speculative clean technologies, means that stabilizing or reducing CO_2 emissions without considerable external financial and technical assistance would almost certainly significantly damage their economic development. However serious the issue, development to meet basic human needs cannot be impaired to address the uncertain consequences of climate change decades ahead, especially when the great majority of emissions have arisen from the richer countries.

At the same time, others consider that industrialized countries are receiving an inordinate amount of blame for the global warming problem or are being pressed into bearing an inordinate share of the cost. They cite the Montreal Protocol as a good example of industrialized countries' commitment to address global environmental problems themselves, and to transfer $200 million to the developing world for its response to the problem. One major concern is the role of population and continued rapid population growth in generating greenhouse gases (and in perpetuating poverty). Another is the ultimate use of transfers that are likely to accompany any global warming initiative, given some of the less successful experiences with waste of aid money and the large size of the transfers involved in many proposals. There are concerns that developing countries may try to "blackmail" industrialized countries with the threat of uncontrolled emissions growth, and the firm belief that this should be resisted.

Finally, both industrialized countries and developing countries eye each other with suspicion when it comes to some institutional arrangements to cope with global warming. Industrialized countries favour institutions (possibly existing ones) that can ensure a decisive role for donor countries. The developing countries would prefer an international institution with a large say for receiving countries, perhaps on a one-country-one-vote basis.

The "North-South" divide is of course not the only one. There are many complex divisions and differences of attitude and interests within each group. Overall, responding to climate change is thus a very complex problem involving major economic and international issues. Since there is no supranational authority that can force a universal agreement or compliance, any international measures will have to be essentially voluntary, though under the pressure of the potentially ominous consequences of inaction.

D. Need for an international agreement

Is action by individual countries, or groups of countries, likely? And would it be effective? These two questions underlie the issue of how important an international agreement would be, and the breadth of participation required.

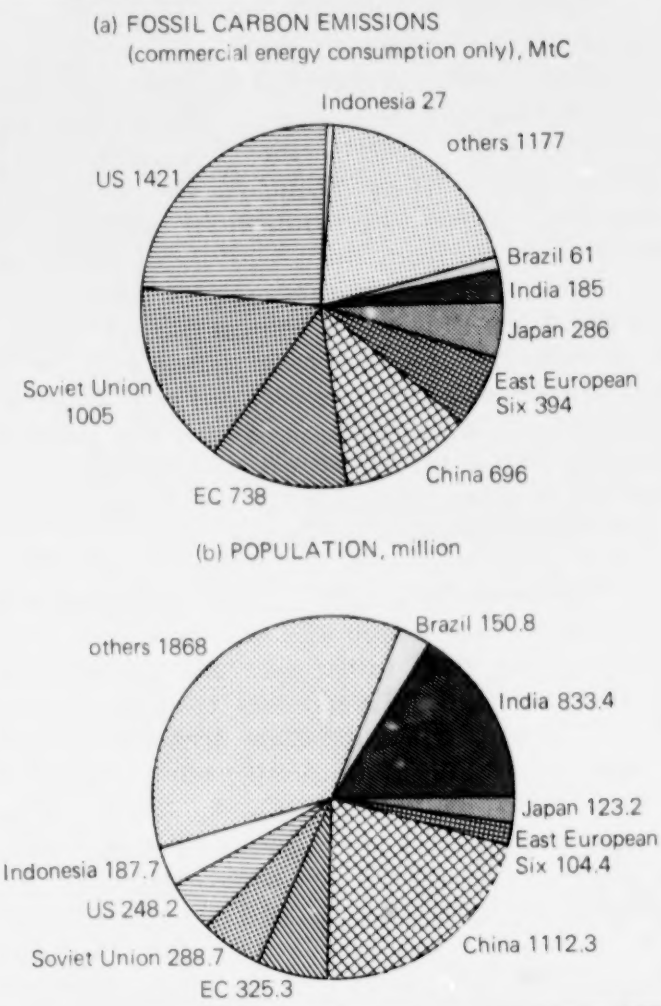
On the first question, a number of countries and regions have in fact made unilateral declarations, and some have passed legislation aimed at limiting CO_2 emissions. The EC, EFTA and all remaining OECD countries other than Turkey and the United States have declared that they will at least stabilize CO_2 emissions at 1990 levels (Japan on a per capita basis), and the United States has stated that it expects to stabilize overall greenhouse gas emissions, with the phasing out of CFCs and other measures to offset growth in CO_2.

These countries have acted from a variety of motives, for example: a desire to be leading the process, backed by a belief that nothing will happen unless some of them take the lead; domestic political pressure; and a conviction in some that initial steps need not be economically damaging, and indeed could be beneficial to the extent that they help to reinforce efforts to promote things that are desirable in themselves, such as improved energy efficiency.

However, such unilateral actions are unlikely to be sustained beyond the point at which substantial economic costs or political difficulties are encountered, or the competitive position of domestic industries is damaged. Furthermore, those countries that have already sought to stabilize CO_2 emissions only account for a limited fraction of global emissions. Figure 3 (a) shows the estimated emissions of CO_2 from the nine most populous countries and major economic groupings in 1988 (prior to the changes in Eastern Europe), together with (b) the distribution of population there. The United States was the largest emitter followed closely by the former Soviet Union, then the EC with 13 per cent. These three together accounted for more than 50 per cent of the global total. Adding the Eastern European countries and China raises this figure to over 70 per cent. An international agreement could thus in principle have a considerable impact, even if it included relatively few key actors, provided the Eastern European countries would act together.

Figure 3

DISTRIBUTION OF FOSSIL CO_2 EMISSIONS AND POPULATION, 1988



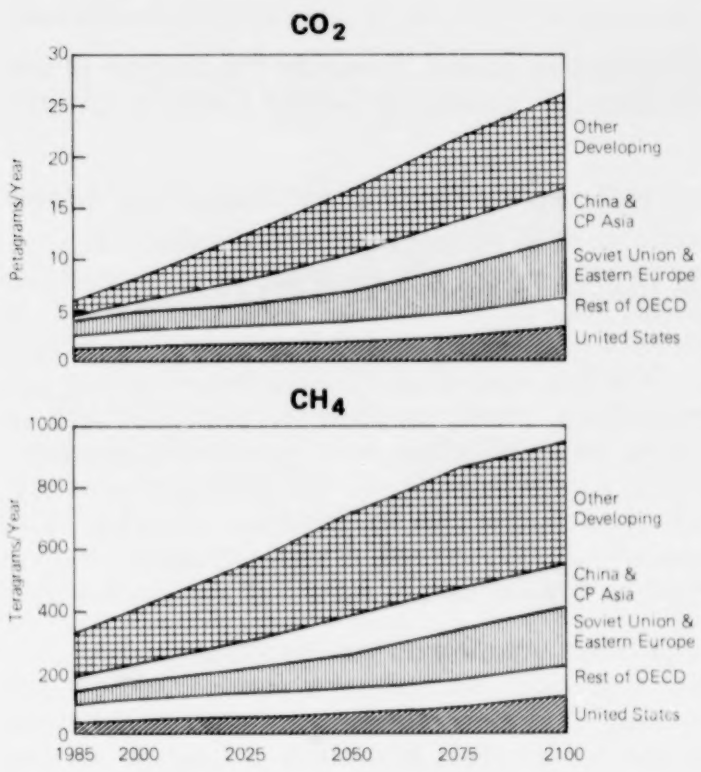
Source: (a) derived from *BP Statistical Review of World Energy*, June 1989; and (b) *The World Factbook 1989*, CIA.

In practice this appears less promising. It is unlikely that such a group of countries would enter into an agreement without the participation of most of the rest of the world, in part because of fears about giving competitive advantages to non-participants. Also, limiting the use of fossil fuels in some countries would tend to lower the global price of fossil fuels, thus encouraging greater consumption in non-participants and partially offsetting the environmental benefits of the action.

Furthermore, as indicated in figure 3(b) the industrialized countries which account for the majority of current emissions by no means correspond to the regions of highest population - the developing countries - in which there is great potential for future growth in emissions. Also, the distribution of other gases and sources (except CFCs) tends to be somewhat more even than that of fossil CO_2. Figure 4 illustrates both these points by showing projected emissions of CO_2 and CH_4 over the twenty-first century in a "rapidly changing world" scenario from a study by the United States EPA issued in 1990. In the scenario the world is divided into five regions:

Figure 4

PROJECTED EMISSIONS OF TOTAL CO_2 AND METHANE BY REGION OVER THE TWENTY-FIRST CENTURY



Source: Lashof, D.A. and D.A. Tirpak, "Policy options for stabilising global climate". Report to Congress, EPA (Washington, D.C.: December 1990).

Note: These graphs do not include natural emissions.

United States, the rest of the OECD countries, the former Soviet Union and the former centrally planned Eastern European countries, China and centrally planned Asia, and the other developing countries. By examining this graph from 1985 through 2100, it is easy to see how the addition of different groups at different periods will affect the possible total reductions.

If the United States stays out of such a system, about 20 per cent of overall greenhouse gas emissions would initially not be subject to control. If the system were limited to the other OECD countries, the effect of even very stringent reductions would be greatly limited. For long-term abatement it is crucial to gain the long-term participation of major developing countries, especially China and India, because of the great increases in population and in consumption of soft coal (which has a high carbon content) projected in those regions. The study from which this graph is derived concludes that the share of radiative contributions from developing countries increases from about 40 per cent currently to about 60 per cent by the year 2025 in the "rapidly changing world" scenario, a figure which could be much higher still if the industrialized countries alone limit emissions.

Thus, while the inclusion of the developed world initially is crucial, the contribution of developing countries is already significant and for long-term and substantial abatement they must be included over time. In practice, given that changes in energy systems and land use cannot occur suddenly but reflect the cumulative effect of policy over decades, it is highly desirable to include countries with large potential growth as soon as possible.

In view of the issues discussed above, negotiations towards a global Framework Convention on Climate Change started in February 1991 under the auspices of the United Nations General Assembly. This Convention, due to be signed at the United Nations Conference on Environment and Development (UNCED) in June 1992, will establish initial measures and the structure and principles on which subsequent protocols to the Convention will be based. The Convention itself may include some preliminary commitments, and will do much to set the options for subsequent negotiations on effective emissions limitation. An efficient global system of control is unlikely to be created in one step, but it is important for the Framework Convention to set the right context and for subsequent protocol negotiations to consider the best options for structuring an evolving system to address the threat of climate change. This study examines one of the options for trying to structure an emissions protocol, and the way in which such a system might evolve from preliminary steps taken in a framework convention.

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* This comprises the IPCC Overview and the Policymaker Summaries of the three IPCC Working Groups and of the Special Committee on the Participation of Developing Countries (in one volume) and the three reports of the Working Groups (in three volumes).

Chapter II

OPTIONS FOR AN INTERNATIONAL AGREEMENT

Michael Grubb*

Summary

An international agreement to limit climate change has to meet many diverse needs, but the central requirements are that it should be both equitable and efficient. Many approaches to an international agreement cannot satisfy both, so the choice of policy instrument is important. Approaches that exploit the flexibility of international market-based instruments, but can leave countries with sovereign authority over the internal policies they use in responding to the resulting incentives, seem particularly promising. These include international tax systems, offsets and internationally tradeable emission entitlements. Their great attraction is that they separate the question of where abatement can be undertaken (hopefully, at the lowest cost), from the question of who should pay, which is determined by the initial allocation/targets, or tax redistributions. By so doing, reasonable efficiency is assured and negotiations can concentrate on the issue of equitable distribution of costs.

An agreement may eventually need to rely on one primary international instrument, but some combinations would be possible, and could develop over time. Offsets, in particular, could evolve from existing commitments to targets, and these in turn could be transformed into a fuller and more flexible system of tradeable emission entitlements, which appear to be a particularly promising long-term option for efficient and equitable global control of greenhouse gas emissions.

Several factors dictate that great care should be taken in trying to formulate an international agreement to address climate change. The scale of the issue has been noted - human actions are changing some of the basic planetary systems that regulate the climate on which humanity depends, but some policy proposals for abating emissions have been estimated to cost many billions of dollars over the next few decades alone. Rapid abatement could damage national economies and may be particularly burdensome to developing countries, especially if the proposals are poorly formulated and inefficient, but inadequate abatement could prove still more damaging. Decisions made over the coming months and years will have consequences for decades ahead. This chapter outlines some of the key issues and options for trying to formulate an abatement agreement.

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* The Royal Institute of International Affairs, London.

A. Criteria for an agreement

An agreement on limiting the accumulation of greenhouse gases needs to meet a wide range of demanding requirements. It must attract the participation of many diverse countries. It has to be environmentally effective in achieving its goal, and thus needs to provide both adequate incentives for the use of cleaner technologies, and the resources required for the poorest countries to adopt them. It must be sufficiently robust for the overall structure to last decades so as to avoid repeated and damaging renegotiations of the fundamental deal, but flexible enough to adapt to developing scientific and economic understanding of the problem with respect to its overall seriousness, the nature of the sources and sinks involved, and the costs of abatement.

Underlying these requirements are two main general criteria for an international agreement. First, it must be equitable. An agreement that is not widely perceived as fair, but that principally reflects current dispositions of economic and political power is unlikely to gain widespread participation or to last as international circumstances change.

The key difficulty is naturally that there are many differing perceptions of what would be equitable, as discussed in chapter V. There are nevertheless some basic principles that can and should command broad support. The richer countries that have caused the vast majority of atmospheric changes to date, and are still emitting at far higher per capita levels than poorer countries, must bear most of the responsibility for slowing atmospheric changes. Those that are still struggling to meet basic needs for their citizens, and have made negligible contributions to the problem to date, cannot and should not be expected to bear significant costs in preventing impacts that will be felt most keenly some time in the next century. It follows that if developing countries are to bear significant costs in limiting emissions in the near future, equity demands that there be some resource transfers from the rich countries to the poor to help them implement the policies required to adopt cleaner technologies as these develop.

Indeed, a system that is clearly inequitable would also be impractical. Developing countries would be unlikely to join a greenhouse control programme that did not take account of differential ability to pay and differing responsibilities. Even if they did, the pressures of capital shortage and debt repayment make it politically impossible to divert existing resources towards preventing an uncertain and very long-term threat, as recognized by the IPCC Special Committee on the Participation of Developing Countries. An equitable agreement would thus also be one that provides the essential resources for globally more sustainable paths of development for poorer countries. The degree of assistance involved and the terms on which it is given are clearly contentious issues of negotiation, and any deal will have to face the constraints of political reality reflecting in part differing equity perceptions. Nevertheless, if developing countries are to be involved, an equitable arrangement involving some resource transfers appears not only fair but essential.

Many doubt the ability of equity to rally an agreement, especially since the majority of equity concepts require some degree of altruism. Sceptics may regard equity arguments as mere public relations cover for raw interests or underlying power relationships. But while the realities of self-interest and power will be important in constraining what is possible, in practice equity considerations have consistently appeared, to some degree at least, in a large number of negotiated international environmental and natural resource regimes (Oran Young, 1989; Morrisette *et al.*, 1991). There are also precedents for large-scale resource transfers for the common good, as with the Marshall Plan and current action and proposals for assistance to the Eastern European countries and the former Soviet Union.

But equity is not the only criterion. The extraordinary scale of the greenhouse problem means that an agreement must also be efficient: the environmental goals must be achieved at the lowest possible economic cost, or at least the system must not be inherently wasteful. An agreement that is economically efficient, and thus involves the least costly way of meeting a given abatement target, is also environmentally efficient, because it enables the greatest abatement to be

achieved for a given expenditure.[1] As the gap between projected emissions and those required to stabilize atmospheric concentrations is so large, and few expect sufficient resources to be made available to stabilize the climate, economic efficiency is also a crucial requirement for an environmentally effective agreement.

Economic efficiency is likely to be a major political requirement as well, especially for the richer countries which in any equitable agreement would bear most of the costs involved. Doubts are expressed not only about the political feasibility of large-scale resource transfers, but about the extent to which they would really be well spent in addressing the problem. The political prospects for reaching an agreement that does involve large-scale resource transfers will be much greater if the arrangement is seen to be economically efficient, with minimal waste of the resources spent. As noted below, and irrespective of equity considerations, global efficiency also implies a need for resource transfers to poorer countries which would not otherwise exploit globally cost-effective abatement opportunities.

Most other requirements for an effective system follow from these two criteria. For example, while an initial system of quantified control, to be practicable, may have to focus on a few major and well understood sources (notably CO_2 from fossil fuels, given their central role and relative ease of monitoring and verification), to enhance efficiency the system should also allow, and if possible encourage, expansion to include additional sources and sinks of greenhouse gases as knowledge improves. Also, as noted above, the system needs to be flexible enough to adapt to changing perspectives on the degree and nature of the abatement required, and it should be able to expand to include new members without complete renegotiation.

The central requirements, however, are undoubtedly equity and efficiency. An environmentally effective agreement will only be possible if it is based soundly upon these twin pillars. It is the potential tension between these criteria that may pose some of the greatest difficulties in trying to craft any agreement, and it is the need to reconcile the two requirements that has led to consideration of new forms of agreement, including the possibilities analysed here. First, this chapter examines the broader range of options that have been proposed.

B. Emission targets (non-tradeable quotas)

As noted in chapter I, a number of countries or regional groups have already declared targets to limit emissions, with most of them aiming to stabilize CO_2 emissions at 1990 levels by the year 2000. These have been very important in establishing the significance of the issue and creating the political impetus for negotiations, and some country targets have already precipitated policy measures that will help to limit emissions. Many expect an international agreement to be based fundamentally on agreement over national emission targets.

This is partly because the approach has many precedents. The Montreal Protocol, the United Nations Economic Commission for Europe (UNECE) agreements on sulphur and nitrous oxides, and the EC's Large Combustion Plants directive on sulphur emissions, are all major environmental examples. The International Monetary Fund and the World Bank have used quotas in financial dealings.

The use of emission targets is economically more efficient than procedural requirements that specify technical control mechanisms (e.g. mandated levels of energy

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1 Ideally, if a complete cost-benefit analysis of global warming could be undertaken, economic efficiency would dictate a cutback of greenhouse gases to the level at which global marginal cost of abatement would equal global marginal gains in terms of avoided damage. In practice, the uncertainties concerning the impacts of climate change and how to evaluate them are so vast that an 'objective' consensus on the costs involved is highly unlikely. Thus the emphasis is likely to be on the cost effectiveness of meeting politically-determined abatement targets, and this chapter uses the term efficiency in this sense.

efficiency or renewable sources, use of CO_2 scrubbing, use of particular methane abatement techniques), because it leaves countries free to decide on the most appropriate means for limiting emissions. But for CO_2 there are important drawbacks that must be considered.

Even within the developed world, widespread variations would make an agreement based upon equal percentage reductions (as in most of the agreements cited above) difficult and inefficient. Certain countries have already taken major measures to limit fuel use (as some did during the 1970s); they consequently have emissions substantially below average in per capita and per GNP terms, and would argue for more lenient targets. By contrast, other countries have easier opportunities arising from greater current inefficiencies or extensive gas or non-fossil energy resources. The inclusion of deforestation and other sources would add further layers of variation. Some countries could thus incur substantial costs in achieving relatively modest reductions, while others could reduce by much more at less cost. If they were bound to equal reduction targets, many relatively cost-effective options for reducing emissions could go unexploited, so such an agreement would be both inefficient and hard to negotiate; an efficient target system would require differentiated national targets. The possible need for revision as countries learn more about emission trends and abatement costs and opportunities adds further complexities.

Irrespective of efficiency considerations, differential targets would be unavoidable if developing countries were to be involved, since, for most of them, the question is not how to reduce carbon emissions but how to limit the rate of growth of emissions while developing, and how to finance the programmes for their limitation. Furthermore, as discussed above, international transfers would have to be separately negotiated if developing countries were to take part, further magnifying the difficulties of negotiating country-specific targets.

Many of these problems arise from the fact that an agreement based upon national emission targets is inherently neither equitable nor efficient.[2] Attempts to adjust targets to make the system more equitable, which, in the absence of an additional agreement on resource transfers, might mean largely excluding developing countries, also make it less efficient, and *vice versa*.

Finally, in negotiations all countries would endeavour to find some arguments why they should reduce emissions by less than the average sought, and inevitably there will be an abundance of "special cases"; the incentive in such negotiations will always be to prove how difficult it is to limit emissions so as to gain a more lenient target. More complex target formulae can be suggested, but they all face considerable drawbacks, including more general questions about the timescale and revision of targets if national circumstances change.

A number of these points have been illustrated by the attempts within the European Community to reach agreement on how to share the EC's umbrella CO_2 stabilization target. The attempts eventually broke down amid suspicions that some member countries were working from unrealistically high baseline projections, and/or not offering as much abatement as they should, so that the national targets did not add up to overall stabilization. The EC has instead opted for a variety of Community-wide policy measures, with a central focus on an EC-wide carbon tax.

Thus, despite the attention this approach receives, it seems unlikely that a long-term agreement to limit climate change effectively can be achieved by a global agreement on national emission targets, and even if some initial agreement were reached the lack of flexibility would make it an inefficient outcome which might not prove very long lasting. Other options need to be considered.

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2 In principle, a globally efficient outcome could be achieved by setting emission targets such that all countries incur the same marginal cost in meeting them. This, however, would be extraordinarily difficult to define because of the difficulties and uncertainties involved in projecting emissions and costing abatement. Also, because poorer countries are generally less efficient, it would tend to imply greater cutbacks (relative to baseline) in developing countries, and greater ***total*** costs for them, although they contribute relatively much less to the problem. Without additional transfers, making the targets more equitable would then involve leaving cheaper abatement opportunities in poorer countries unexploited.

C. Agreement on domestic carbon taxes

Whatever form of agreement is eventually adopted, many countries may choose to use market-based instruments as part of efforts to limit emissions. These would penalize CO_2 emissions and provide an economic incentive to use more efficient and lower-CO_2 technologies.

Two main forms of economic instrument are possible for domestic pollution control. One is the use of tradeable entitlements or permits, as applied particularly in the United States; some of this experience is described in chapter IV. Domestic tradeable entitlements might be a viable way of implementing unilateral or agreed emission targets. The other main option would be to use carbon taxes. Environmental taxes, if properly set, compensate for the social and environmental costs of activities that are not captured in the market price. For limiting emissions of CO_2 they would probably be applied to the consumption of fossil fuels in proportion to their carbon content. The revenues, which could be huge in addressing global warming, can be used to offset conventional taxes or for a host of other purposes.

A general discussion of market-based instruments for domestic control of greenhouse gas emissions is beyond the scope of this chapter (for a recent general discussion see Pearce *et al.*, 1989). There are doubts expressed about their environmental effectiveness and possible impact on the poor (concerns addressed in the international context below). But many now recognize that, provided the market concerned works reasonably well, such instruments can provide an effective and efficient means of control, and that distributional impacts on the poor can be mitigated.

An increasing number of governments are using pollution taxes in domestic policy, and one suggestion for an international agreement is that it should focus on determining levels of domestic carbon taxes.[3] An agreement to apply domestic taxes up to a certain level could well be favoured by many industrialized countries (though not the United States). It would not involve placing significant resources under international control - or globally if the markets worked well - and, other things being equal, it would not be obviously discriminating between countries.

The drawbacks arise because other things are far from equal and energy markets are far from ideal. Not only do stages of development differ, but so do economic systems, price structures, and existing taxation and other policies. Many countries, both developed and developing, already tax oil consumption and subsidize domestic energy production to widely varying degrees. Meaningful agreement on domestic tax levels would be very problematic with such wide differences in national policies. The social and political implications of domestic carbon taxes would also vary considerably between different countries. In many areas of the world people cannot afford commercial fuel without subsidies, still less if taxes were to be added. False pricing of fuels is responsible for many problems (Kosmo, 1987) and some options are available for softening the impact of removing subsidies and/or adding taxes; but in certain cases there are good reasons for current practice, and in all cases the political obstacles to major changes are substantial.

Furthermore, such an agreement would not have the same impact on different countries, and equal tax levels would, by a considerable margin, be most prejudicial to those countries that are poor and rely most heavily on coal. An agreement that merely stipulated equal domestic CO_2 taxes would therefore not necessarily be efficient, and it would certainly not be equitable; not only would it fail to provide any resource transfers to help the poorest countries, but it could hurt them the most.

To overcome these difficulties, an agreement might be considered in which there would be different tax levels for different countries, together with separately negotiated international transfers. Such possibilities could be further examined, but they might reduce the efficiency of this approach, while

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3 For a general analysis of carbon taxes, including international issues, see the collected papers in Dornbusch and Poterba, 1991.

adding considerably to its complexity, and would imply that an agreement on domestic taxation cannot be the only international instrument used, or perhaps even the main one.

Agreements on carbon taxes could play an important role among some groups of closely aligned countries, as in the case of the recent EC proposals to introduce an energy/carbon tax throughout the EC, which would test the impact and practicality of such a system (Pearson and Smith, 1991). But for broader application there are important issues of sovereignty and differing economic circumstances and ideology to be addressed. In a world where social and economic conditions and beliefs vary so radically, it is hard to see how an agreement can be based primarily upon national carbon taxes, or indeed upon any other agreement that specifies domestic policy.

Although an agreement on domestic carbon taxes appears to be a market-based approach, it is so only in the sense that it obligates the countries involved to use carbon taxes. This is not the same thing as exploiting the potential efficiency and flexibility of market-based instruments internationally. Indeed, economically, it has much in common with an agreement on national emission targets in which countries agree to implement their targets using domestic tradeable emission entitlements, and as such it faces many of the same problems. The real need is for mechanisms that provide the flexibility required to meet both equity and efficiency requirements internationally.

D. International market-based instruments: an overview

It is possible to consider the use of market-based instruments internationally. Three main options have been advanced for achieving this: an international emissions tax; external offsets; and internationally tradeable emission entitlements (or "permits"). These three options are explained and discussed in turn below, but a few general points common to all will first be considered.

Market instruments seek to deter pollution by making it more expensive, so that those involved decide to reduce emissions to avoid the associated costs. This contrasts with approaches that directly stipulate the degree of reductions by each party. Initial debate on such instruments has revealed at least two key concerns. One is that such an approach would be environmentally ineffective, because it would not directly mandate limits on each country's emissions. The other concern is that it would be inequitable, because it would allow richer countries to carry on polluting whereas poorer ones could not afford to do so.

The first concern, that a market-based instrument would be ineffective and could indeed be seen to "legitimise pollution", is badly misplaced for most circumstances. In the case of many pollutants it is neither practical nor even desirable to ban emissions entirely; this is certainly true of CO_2 and the use of fossil fuels. The question is how best to limit emissions to environmentally acceptable levels. Emission targets and all other approaches similarly "legitimise pollution", the difference being that market-based instruments would not allow this to occur for free, but would penalize emissions and thus give a continuing incentive to reduce them as long as the costs of limitation were lower than the penalties imposed.

Providing that the economic incentive is set at an appropriate level and that the market concerned works reasonably well, a market-based instrument can be more effective because it gives a general and flexible incentive. Those involved can explore all the options for limiting emissions both within their own country and elsewhere, and there is a direct incentive to look into abatement opportunities anywhere and to develop and deploy cleaner technologies that can avoid the pollution and consequent penalty.

As noted above, economic efficiency also leads to environmental efficiency, because it makes for the greatest abatement for a given expenditure. Thus, in practice, because countries have the freedom to decide how and where to pay for limiting emissions, they are likely to agree to more stringent cutbacks than would be the case if all countries were bound to fixed targets that allowed no flexibility (and offered no incentive to cut back beyond the agreed target if this turned out to

be cheaper or easier than originally envisaged).

Whether or not a market-based instrument is more or less equitable than any other approach depends entirely upon how it is structured. Because the system would be created from scratch by negotiated agreement, its form and distributional implications would be determined by negotiated settlement rather than the "vagaries of the market". All international market-based instruments would of necessity involve international resource transfers (just as domestic markets involve the exchange of goods or money), and, as discussed in this chapter, a market-based system could readily be structured to ensure that poorer countries were the net gainers from the international resource flows - indeed, they would not take part unless this were the case. They pay for their emissions ("at the margin" as emissions increase), but this would be more than offset by their overall receipts.

One of the key attractions of such an approach is thus that it can provide simultaneously an efficient incentive to limit emissions and the resource transfers from rich to poor (reflecting international disparities in wealth and emissions), which would form an essential part of any equitable and practical agreement involving limitations in developing countries. More generally, a key feature of a market-based arrangement is that it can separate the question of efficiency from that of equity, and can in principle achieve both simultaneously. Negotiations on an equitable arrangement could thus proceed in the knowledge that money spent would be less likely to be wasted, thereby improving the political prospects for a more equitable solution.

It is important to note that one question that is ***not*** unique to international market instruments is that of deciding how to share the costs. This issue of allocating costs is unavoidable whatever control system is adopted, whether it be national emission targets, taxes, or other approaches. All systems that have a considerable global impact will impose costs on participants, and must include some resource transfers if poor countries are to take part. The use of a market-based approach neither creates nor solves the problems of allocation and burden sharing, which will have to be addressed in any substantive agreement. But if the political debates about the appropriate degree of abatement and burden sharing can be resolved, they might in principle offer a powerful and efficient way of implementing the intention.

There are, of course, many complications and unanswered questions about how such systems could be created and would operate in practice. The rest of this chapter reviews some of the specific options, and later chapters will examine more closely the detailed issues involved in implementing the most promising options.

E. International emission taxes

An alternative - or complementary - option to an agreement on domestic CO_2 emission taxes could be for some or all of the revenues from carbon taxation to be disbursed internationally. The revenues would thus be paid in proportion to emissions, and redistributed in such a way as to ensure a net transfer from richer to poorer countries. Governments would then face an equal incentive to exploit opportunities for abatement, ensuring efficiency, and this would be achieved independently of how the revenues were redistributed, which would reflect a negotiated equitable outcome. Although this might appear to imply agreement on using taxes domestically, this is not necessarily the case. In principle, taxes could be applied to countries on the basis of total national emissions, leaving governments with the freedom to determine the extent (if any) to which the taxes would actually be passed on in fuel prices. Unlike an agreement on domestic taxes it separates the question of efficiency, which in principle follows from the use made of the tax instrument, from that of fairness, which depends upon how the revenues are disbursed.

There are two very different ways in which an international emissions tax could be implemented. One option would be for the revenues to go to a central international fund. However, this raises major problems of scale

and management. A carbon tax sufficient to make a serious impact on industrial choices could raise hundreds of billions of dollars globally (compared with the current annual registered budget of the United Nations of about $1 billion). It seems implausible that countries would willingly hand over amounts a hundred times larger than current United Nations contributions to international control, and create the bureaucracy required to manage dispersal of this, perhaps on a project-by-project or plan-by-plan basis. Apart from the magnitude of the payments involved, it is hard to see how a bureaucracy managing such vast sums would operate in practice, deciding which countries should receive money for which projects. In practice it seems questionable whether such an approach would turn out to be efficient, or even fair, because it could readily be subject to political distortion of the decisions on how to spend the money raised.

While this approach might be feasible for managing relatively small amounts, in view of the scale of resources that could be involved in any general agreement on carbon taxation for abatement or required to involve developing countries in substantial abatement efforts, it might be both impractical and undesirable to have all the money controlled by an international bureaucracy.

This partly explains the interest in a different approach whereby revenues from agreed taxes would be redistributed according to an allocation formula, or "reimbursement parameters", as suggested by Hoel (1991). This is, in fact, the only form of international agreement on taxes that Hoel considers a real possibility. It overcomes many of the objections to other carbon tax approaches, and deserves more study (it has, in fact, much in common with proposals for a global scheme of tradeable entitlements as discussed below). It is important to recognize, however, that it is not what many studies have in mind when referring to an agreement based on carbon taxes.

F. External offsets

The idea of ***external offsets*** is that a given actor (which could be a firm, industry, region or country) has an initial target, but is allowed to "offset" this by investing in measures to reduce emissions by an equivalent amount elsewhere.[4] In the international context, external offsets would imply that countries with an agreed national emission target could meet this either by curtailing their own emissions to this level, or by investing elsewhere to reduce emissions so that the total of national emissions minus the amount saved by those external investments would meet the target. The idea would be to increase efficiency and flexibility by allowing countries to fund abatement in places where it might be cheaper than measures undertaken in their own country.

The great attraction of external offsets is that they would enable efforts to limit greenhouse gas emissions to be spread globally, without necessarily having a global agreement on commitments. For example, it would be quite possible for industrialized countries to agree to emission reduction targets on the understanding that offsets in other countries could contribute towards the target. Offsets would thereby become a means of some resource transfers for abatement, and, because they would broaden the scope of abatement investments and enable countries to look for the cheapest abatement opportunities, it should be possible for the countries adopting targets to declare or agree to greater cutbacks than would be feasible without offsets. Thus offsets could in principle allow for both greater abatement and a degree of resource transfers without involving the developing world in multilaterally negotiated commitments (though obviously, offsets could only be used through case-by-case agree-

[4] As discussed later in this study, ***internal offsets*** could also be considered in which firms or countries could be credited with the radiative benefits of investing in abatement of emissions through sources and sinks that are within the territory of participating countries, but are not formally part of the main controlled emissions. The key difference is that external offsets would involve investments in countries that need not formally be part of the target or agreement, whereas internal offsets would involve investments in sources and sinks within these territories. Some of the issues involved in this are discussed in chapter VIII on Implementation.

ment with the countries in which offsetting investments are made).

Offsets are potentially important policy tools, but in the international context they could be rather constrained by the problems of ownership, monitoring and measurement. Many forms of offset would imply a degree of direct investment and perhaps ownership of assets by one country or firm in another country. Difficulties of assigning responsibility could be encountered, for example, if a project failed to "offset" the emissions originally envisaged. The need for monitoring and guarantees could give rise to issues similar to those raised by conventional foreign direct investments. The implications would require careful consideration.

Another important feature is that an offset system requires the emission reductions associated with individual schemes to be measured. This could be problematic. How much would be saved by a given incentive to slow deforestation? How much would be saved by a household conservation scheme, renewable energy subsidies, or public transport investments? In all cases, it depends upon the level of activity that would have occurred in the absence of those measures, which is often unknowable. Some particular projects may be more manageable. Perhaps the simplest might be investments in particular non-fossil energy facilities that directly displace fossil power. The CO_2 absorbed by specific forest plantations might be adequately measurable, though even this could raise difficulties.[5] There are thus practical issues surrounding the use of external offsets which do not rule them out but will constrain their scope.

Finally, since offset transfers would be primarily from countries that adopt emission targets (and offset them) to those that do not, a system based on offsets is relevant primarily in terms of industrialized country commitments, and would involve developing countries primarily in responding to proposals for offsets on their territories. This is unlikely to prove a satisfactory long-term basis for global control; it is also questionable how long industrialized countries would sustain such transfers if there were no subsequent commitments from receiving countries. However, because external offsets are a relatively simple extension of emission targets, which would help to extend their coverage and increase their overall efficiency, they could usefully be a feature in the earlier stages of an evolving control regime. In fact, they could act as a natural stepping stone towards more comprehensive forms of international control (Grubb and Sebenius, 1991), notably a system of tradeable emission entitlements (see chapter III). This potential needs to be explored and considered even within the context of the Framework Convention itself.

G. Tradeable emission entitlements

Tradeable emission entitlements (sometimes called internationally tradeable or marketable emission permits) share some of the features of offsets but differ in other respects. Negotiations would define an overall target for emissions for all the participating countries (which could vary over time) and "entitlements" or "permits", would be issued equal to this total, together with an initially agreed way of allocating them among the participating countries (in practice, the overall target and allocation would probably be negotiated together, as discussed in chapter VI).

After the system comes into force, participants would have to hold entitlements equal to their total emissions. If their initial allocation was insufficient, they would have to obtain entitlements from others that had some to spare, through bilateral trading. As a result there would be a direct incentive for all countries to minimize emissions (either to minimize the payment for entitlements or to maximize the revenue from selling them) irrespective of whether they were meeting some predefined national target. If, as a result of the initial allocation, developing countries were to hold excess entitlements, these

5 The rate of carbon accumulation can vary widely depending on many factors, including good long-term forest management. Plantations would have to be closely monitored to establish the real CO_2 absorbed. If the offset credits depend upon continuity of absorption (as would be expected), this might imply a degree of direct foreign ownership and interest over land resources in another country, which naturally raises sensitive issues.

could become a powerful mechanism for resource transfers: developing countries could lease or sell their excess entitlements to the industrialized countries that need them in return for finance or technology.

The concept of tradeable entitlements has been attacked as giving immoral "permits to pollute". As noted in the general discussion above, this criticism is not well founded. Emission standards and targets are themselves "permits to pollute"; if making them exchangeable provides a more practical, desirable and efficient means of control, that is all to the good. That "if" is the useful area of debate. There are many complex questions that need to be addressed concerning the allocation, management and practical operation of such a system, as compared with the alternatives. It is upon these issues that this study concentrates, but a few general points may be noted here.

In many respects, there are similarities between a tradeable entitlement system and an international tax system. The question of how entitlements are allocated initially is directly equivalent to the question of how tax revenues should be distributed. A process of repeated negotiations on country-by-country allocations would have much in common with an international tax being paid into a central fund with negotiations on its disbursement. An allocation formula for tradeable entitlements is closely tied to Hoel's suggestion of "reimbursement parameters" for the redistribution of tax revenues.

There are, however, important distinctions. The most striking difference is that tradeable entitlements are a way of ensuring that a given emission target is met, and expenditures follow from the costs involved in achieving this. This contrasts with a tax which regulates expenditures, not emission levels directly. Another difference is that a tax would presumably involve direct monetary transfers, whereas entitlements could be exchanged in other kinds of deals, for example in return for specific kinds of technology and development assistance. This might prove politically more appealing, though potentially more complex. In general, an entitlement system could rely more upon arrangements negotiated between individual countries (or groups of countries) following establishment of the system itself, and would give governments more control in deciding how and where to conduct transfers.

It might be possible, however, to pass on some of the entitlements to industries which could then be involved directly in international entitlement trades with companies in other countries whose governments have acted similarly (e.g. Bertram, 1992; Harrison, 1990). A "mixed" trading system within which there are government-to-government trades of entitlements as well as unfettered trades between private companies and governments might be possible. Governments would still have to be internationally responsible for ensuring that the total of government + corporate entitlement holdings matched the national total emissions, but allowing trading at a lower level could exploit abatement opportunities more effectively. If the managerial issues raised by having mixed ownership of entitlements can be overcome, the efficiency gains could be substantial.

Unlike offsets, monitoring of a tradeable permit system would focus upon measurement of total emissions of the controlled gases by each participant, rather than the amount saved by particular investments. There is thus no need to estimate what emissions would have been in the absence of abatement measures, but only what they are. The measurement and monitoring issues are therefore much simpler than with offsets. Moreover, there are no problems concerning foreign ownership, because it is the entitlements that are transferred internationally rather than direct offset investments. But because this is a system that relies upon trades of quantified emission levels, it could (unlike a tax-based system) develop relatively easily from arrangements involving external offsets.

A potential drawback with tradeable entitlements is that if some countries or closely aligned groups of countries have a significant fraction of the "spare" permits, they might be able to exploit market power to gain unfairly by distoring the transfers, which could make the system both less equitable and, in principle, less efficient than a tax-based agreement (Hoel, 1991). Southern diplomats fear that the economic power of the North could be exerted to somehow force a very low price for the transfers; Northern countries fear emergence of an OPEC-like cartel of developing countries selling their surplus entitlements only at greatly inflated prices. In fact, the extent to which either could be done would be limited by the fact that an agreement could only tolerate a certain amount of abuse before disadvantaged countries would withdraw, and by more direct measures to counter such distortions, as discussed in this study and elsewhere (Grubb and Sebenius, 1991).

Obviously, a key issue would be the initial allocation of entitlements, which would determine the distributional implications of the scheme. But, as noted above, this is not an issue that is unique to such a system; examining options for the allocation of tradeable entitlements is merely one way of addressing the equity issues explicitly.

A number of studies that have examined the options for implementing an agreement on limiting CO_2 emissions have concluded that tradeable entitlements offer the most promising approach (Bertram *et al.*, 1989; Grubb, 1989; Epstein and Gupta, 1990). The IPCC Response Strategies Working Group committee on economic instruments (report IPCC/WGIII-II/Doc.3) concluded that: "Of all the instruments examined, the system of tradeable emission rights [tradeable entitlements] came in for the most attention and was considered to be most promising. It offers the advantages of flexibility, efficiency in pollution abatement, direct control of total emission levels, a mechanism for trading reduction in different gases, and incentives for research into pollution abatement technology".

H. Conclusions

An international agreement on specific measures to limit climate change has to meet many diverse requirements. Two over-riding needs are that an agreement should be both equitable and efficient. There are several policy instruments available for structuring an agreement, but some appear much more promising than others. Those that exploit the flexibility of international market-based instruments, but can leave countries with sovereign authority over the internal policies they use in responding to the resulting incentives, are of particular interest.

The different policy instruments discussed in this chapter are not necessarily exclusive. A carbon tax agreement could in principle contain elements both of domestic and international taxation. National carbon taxes would almost certainly be one component of many countries' policies in response to the incentives of an international tradeable entitlement system, especially if they did not or could not sublet entitlements directly to industry. Certain classes of measurable offsets could be used by some countries taking part in a tradeable entitlement system as a way of extending coverage of efforts to countries that were not part of the system. A small international carbon tax would be one way of raising revenues to administer a tradeable entitlement system, or indeed any other international process to tackle climate change. There are some similarities between different instruments and all need closer investigation.

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Chapter III

FROM OFFSETS TO TRADEABLE ENTITLEMENTS

Kjell Roland*

Introduction

Chapter II has described different ways of trying to formulate an international agreement for limiting emissions, and outlined the possible benefits of using options such as offsets and tradeable emission entitlements. Offsets, as noted in that chapter, are limited in various ways as the basis for a long-term control regime, but they have a clear advantage over a tradeable entitlement system in that they can develop easily as an extension of existing commitments without the need for a detailed global agreement on all aspects of allocation and trading.

A number of individual countries as well as the European Community have unilaterally adopted targets to stabilize their emissions of CO_2 at their present level by the end of this decade. Parallel to the Montreal Protocol on CFC emissions, it seems reasonable to assume that a successful outcome of the ongoing negotiations on a Framework Convention on climate change, at least in a first phase, will have to rely on country-by-country commitments to limit emission of greenhouse gases (GHGs).

The costs of curbing growth or stabilizing emissions at a specific level vary considerably among countries (and from one sector of the economy to another). In general, there is a tendency for the cost per ton of GHG reduction to be higher in developed countries as compared to developing countries and Central and Eastern Europe. However, costs vary considerably even among developed countries. Symmetric pro rata reductions in all countries would entail unnecessary costs to the global society. Global costs can be considerably reduced if reductions are high in low cost countries and low in high cost countries. Accordingly, the Framework Convention should, from the outset, contain the option that country-specific emission commitments can be reached individually or in cooperation with other parties to the Convention. This would make it easier for the OECD countries to accept national commitments and could even convince some developing countries to participate.

In theory, a system could be envisaged in which emission entitlements are traded freely between countries. The United States experience has shown that trade in emission quotas is a very powerful policy instrument to combat environmental degradation. In principle, there is no reason why a similar system of freely tradeable emission entitlements could not be set up at an international level. However, it is our understanding that a full-blown international market will have to develop gradually over a period of time as an evolutionary process. This was also the case when the United States emission trading system was developed. A first step could be to establish an international regime through which nations could cooperate to reach com-

* ECON Energy, Oslo.

mon goals by agreeing to barter financial resources and technology for emission entitlements.

In principle, each country should have the option of deciding whether to achieve the emission goals domestically or in cooperation with other countries. However, if two countries agree to join forces to reduce emissions, this activity needs to meet the conditions prescribed by the Convention. Accordingly, an international agency is needed to monitor and control the activity undertaken to make sure that the corresponding adjustments in national emission quotas are legitimate.

As in the case of the United States Clean Air Act, it is useful to draw a distinction between tradeable emission entitlements and offsets. Offsets in the United States system refer to offsetting investments to reduce emissions from an existing source when a new source is established in a so-called non-attainment area (areas that do not meet the ambient air quality standards). If countries are committed to limit their total emissions to a certain level, emissions over and above these levels could be compensated by offsetting investments in other countries. Our proposal is that a monitoring and control system should be set up to supervise offsets between countries. An offsetting investment in another country should entitle the investor to be granted an emission permit or entitlement related to the emission reductions that the project has produced. Over time this system could develop into a well-organized market for emission entitlements.

The negotiations in the Intergovernmental Negotiating Committee (INC) on a framework convention on climate change leading up to the 1992 United Nations Conference on Environment and Development in Brazil seem to have reached widespread agreement that the climate Convention should allow cooperation among countries for the joint implementation of their national commitments. Three proposals have been put forward so far. Germany has proposed the establishment of a crediting system whereby one country is credited for undertaking measures to reduce GHG emissions in another country. This crediting strategy would give strong incentives for industrialized countries to transfer technology and capital to developing countries and to countries in transition. The German proposal does not elaborate much on the institutional framework needed to implement such an idea.

A similar proposal has been put forward by Norway. The basic idea is that international cooperation to achieve a cost-efficient abatement strategy should be fostered by the establishment of a GHG clearing house (CH). This institutional mechanism should be set up under the Convention to supervise, monitor and control cooperation among countries in order to achieve common goals for reducing emissions of GHGs. In the United States, it has been proposed to Congress (see United States Congress (1991)) that an amendment to the Clean Air Act be enacted requiring large new stationary sources of CO_2 emissions to compensate increases by offsetting investments domestically or internationally. This proposal is somewhat different from the other two in that it is closely related to existing domestic regulations in the United States and is not primarily a proposal as to how entitlements could be transferred between countries. However, if enacted, demand for international offsets by the private sector would be created and thereby the need for a proper international framework.

This chapter reviews how offsets between countries could be established and underlines that offsets should be regarded as the first step towards a trading system for GHG entitlements. A crediting system or an international clearing house for transferable GHG entitlements is needed as the regulatory framework for international offsets. Such a system would introduce flexibility into an international greenhouse agreement founded, in its first phase, on country-by-country emission targets. It is not necessary initially to establish a general system of tradeable emission entitlements within and between countries. However, the CH or the crediting system should be regarded as the first step in an evolutionary process towards an international market for emission entitlements. The challenge at the outset is to introduce flexibility and rational economic incentives into an agreement based on national emission targets when different countries choose to employ differing sets of policy tools to achieve their targets. In this context, we are not concerned with the way national emission targets have come about. We simply assume that a number of countries, primarily or solely in the OECD area, have committed themselves to contain emissions within certain limits.

In this review, no distinctions are made between the different proposals to the INC. However, for the sake of simplicity the term clearing house will be used when discussing the crediting system. It refers to the Norwegian proposal to the extent that it is more elaborate and contains more details on institutional issues than the other proposals.

A. A clearing house for international offsets

1. *Entitlement trading or offsets*

A market for emission entitlements presupposes that all actors have a specified emission quota. On a national level, emission trading has developed in an environment where emissions are regulated by a command and control regulatory system. Internationally, all participating countries must similarly have a specified national emission target. Thus, emission trading is limited to countries which at any point in time have adopted a national emission target, are able to measure total emissions and have developed a credible strategy on how to meet their emission targets. However, an international GHG agreement is unlikely to start with universal participation. It is more likely that, in the early phases, only a very limited number of predominantly industrialized countries will adopt a national emission target.

Offsets merely require the buyer to have a national target. For that reason, offsets could prove to be a powerful instrument for incorporating developing countries and countries in transition into efforts to combat global warming. Important in this respect is the fact that the equity issues involved in allocating emission quotas among nations do not have to be solved before action can commence.

It is argued below that offsets should be the first step in a continuous evolution towards a full-blown market for national emission entitlements. In fact, a development can be foreseen in which international offsets start as a bilateral agreement between two parties, subsequently develop into a market for emission entitlements based on numerous offsets including a GHG banking system, and finally arrive at an international emission entitlement market.

International offsets

In the United States Clean Air Act, the term offsets is used in geographical regions that are not able to meet the ambient air quality required by the law. If no flexibility was built into the regulatory system, no new sources would be allowed in these areas. To prevent unacceptable limitations from being set to economic growth, new sources are allowed, provided emissions from existing sources can be reduced by at least the volume emitted by the new source. Countries that agree to curb substantially the level of their GHG emissions could, as a result, face severe limitations to economic growth. In this chapter, the term international offsets will be used when countries initiate and pay for projects that reduce GHG emissions in another country in exchange for an emission entitlement determined by the reduction in emissions obtained through the projects.

In Dudek and LeBlanc (1990), Dudek (1990) and "The CO_2 Offset Policy Efficiency (COPE) Act of 1991" (United States Congress (1991)), it is proposed that new stationary sources that emit more than 100,000 tons of CO_2 should annually compensate the increased emissions by offsetting CO_2 reductions. Dudek argues that offsets are readily available within the United States. Potential offsets could include, among other possibilities, switching to less CO_2-intensive fuels, increasing sinks by the planting of trees, energy efficiency investments and methane recovery.

On the international level, demand for offsets could arise in countries that apply this kind of domestic regulation in relation to new sources. If companies were allowed to buy offsets internationally, they would buy where it is cheapest, whether domestically or abroad. Alternatively, governments could buy offsets because emissions have surpassed the national target. In both cases, offsets between countries would need some kind of an international body to oversee and certify trade.

2. *A clearing house (CH)*

In order to oversee and control offsets between countries, an international agency is required. General consensus is needed among all parties to the Convention that an international GHG crediting system, i.e. a CH,

is warranted and useful as part of a broad-based effort to curb global warming. This requires all positive and less desirable effects of establishing an international CH to be carefully studied. It is essential for offsets authorized by the CH to be related to national targets for fixing emissions at certain levels (e.g. stabilization). A natural condition for participation is that at least the buying country should have adopted a national emission target. Furthermore, it is essential for the offsetting investments to be introduced in such a way that developing countries are given incentives to participate in the international efforts to slow global warming.

3. *Transferable GHG entitlements*

The counterpart to an offset investment in a country is the transfer of an emission entitlement. Before any transfer in entitlements can take place (or, in a later stage, trade) we have to define the commodity to be traded, determine who is allowed to operate in this market and establish the general rules of the game:

- Define commodities eligible for transfer

The commodity or commodities subject to trade may be defined by the greenhouse Convention. If a so-called comprehensive approach is written into the Convention, transfers of entitlements should (in principle) cover all GHGs and trade between different GHGs should be legalized. However, for a number of practical reasons (in particular the need to monitor, measure and verify emissions), transfers of entitlements might initially be confined to one or a few GHGs, probably only fossil CO_2. In a similar way, the sinks that are accepted as a basis for the transfer of entitlements between countries need to be defined.

- Define potential sellers and buyers

The incentive to buy entitlements is closely related to the question of national emission targets. It is important to stress that national emission targets constitute the basis for international transfers of emission entitlements. The national targets could be defined as stock permits dated on an annual basis. Potential sellers are countries that can offer cheap and powerful GHG reduction projects. Furthermore, if non-signatories of the Convention or countries that have not adopted a national emission target are allowed to participate, offset investments could give developing countries an incentive to participate in the international efforts to combat global warming. However, only countries with a national emission target have the incentive to buy offsets.

Internationally, offsets should give rise to transfers of entitlements limited to the lifetime of the offset investment project. Entitlements should be dated on a yearly basis and be conditional upon actual and verified modifications in emissions.

- Agree on rules as to how transfers of emission entitlements are to take place between countries

Procedures for the transactions (approval procedures, control and monitoring) need to be carefully spelled out, and it has to be determined who is allowed to participate. This is necessary to ensure that transfers of entitlements are in accordance with the Framework Convention and not a way of circumventing it. As transfers of entitlements have to be based on national emission targets, governments will have to participate in and oversee transfers in some way or another.

However, there are good reasons to involve private parties directly or indirectly. Private sector participation is required to make sure that correct incentives are transmitted to the parties responsible for emissions and for undertaking the activities that could modify them. Furthermore, the number of potential actors in the market increases substantially, hence improving the chances of a well-functioning market. The international currency market is a useful analogy in this respect. In the currency markets, Central Banks (i.e. governments) trade alongside numerous private traders.

(a) An international agency

Within the exporting and importing countries, the offset project has to comply with domestic rules and regulations before a licence for international transfers can be issued. Domestic environmental protection agencies or similar regulatory bodies would have to supervise and control this process. Similarly, an international agency is needed to oversee and control international transfers of GHG entitlements. This agency would be responsible for monitoring, tracking, recording and enforcement in relation to the greenhouse Convention and the international community. Before a transfer of entitlements

to another country can be certified by the international agency, it is necessary for emission reductions to be quantified and enforced. The burden of proof would normally lie with the seller. However, if the offset involves a country that is not part of the greenhouse agreement, the burden of proof should lie with the importing government. The point is that if the exporting country does not have a national emission target, the incentive to oversee and control emissions from offset investments is simply not there. The more emission reduction such a country can claim, the more valuable the offset project would be.

To facilitate international offsets, the internationcl body will have to supervise and regulate transfers between nations. Common rules and regulations are necessary in the following areas:

A monitoring system of GHG emissions. This requires reliable information on emissions and sinks (i.e. databases and information gathering). All parties involved in the transfers have to submit detailed information on the activities in question and must demonstrate the net GHG effect during the lifetime of the GHG reducing project.

A tracking and recording system of actual transfers of entitlements. An essential part of this system is an accounting system to track each offset project and the related transfer of entitlements.

A credible enforcement mechanism to ensure that obligations are fulfilled. In particular, in the first phase of an international action plan to reduce global warming, one should not expect any form of legal enforcement mechanism between countries. The penalty for non-compliance will have to rely on non-legal actions by the CH. Two types of sanctions are important in this regard. The CH should publish reports on the performance of each offset investment and transfer of entitlements, and the governments involved should in principle be accountable to the greenhouse agreement even when private parties take part. Bad publicity in itself would in many cases be an effective sanction. However, the CH should have the power to refuse future offset projects or transfers of entitlements involving non-performing countries.

Banking of permits. The CH should have a provision for banking GHG emission rights, i.e. for storing unused entitlements. The seller can store entitlements made available for international trade and the buyer can initiate GHG reducing activities in other countries and draw upon the GHG credits when they are most valuable to him. It is important to bear in mind that global warming is a long-term phenomenon, thus emission in a particular year or even decade is not particularly important, whereas accumulated emissions over decades are. Hence it is no problem if individual countries are hoarding. Similarly, it is not important if a country achieves its emission target in a specific year or not. A guarantee to do so could be costly in itself. The GHG bank should allow countries to concentrate on long-term targets and adopt a strategy to achieve them.

Finally, a greenhouse gas entitlement bank makes it possible to separate permit buyer and seller. Hence a well-organized market among numerous and anonymous actors can develop over time.

A market clearing house needs to be established. A market clearing house means a market-place represented by an institution that organizes the dissemination of information on potential offset investment projects to interested parties and that structures the bidding process or a similar procedure to establish a market clearing price on GHG entitlements.

(b) A gradualist approach

In D.J. Dudek (1990), it is suggested that the trading system could develop gradually. After the above-mentioned institutional framework has been established, transfers of entitlements could be limited to offsets to compensate for new sources of CO_2 emissions or to governments in countries that are unable to meet their national target. New sources in countries with high abatement costs should be allowed to buy CO_2 offsets internationally. To facilitate this transfer of entitlements, a CH might be instrumental and necessary. It should possess an information-gathering system containing information on potential CO_2 reduction projects that need financial and technological support to go ahead.

At a later stage, a full-scale market for CO_2 quotas could develop. In the long run, trade in other GHGs can also be foreseen, and even trade between different gases. In Tietenberg (1991) it is suggested in a similar evolutionary way that trade between different GHGs should be allowed from the start on a case-by-case basis.

4. *Certifying and monitoring international GHG offsets*

The international transfer of national emission entitlements raises a number of problems. Trading a share of a nation's GHG entitlement is far more challenging than trade in ordinary commodities. Important issues, in addition to establishing the necessary institutions to allow the market to work, are equity and fairness between nations, the need for transparency and the necessity of documenting the effects on global GHG:

- Measurement and verification

Projects to reduce emission of greenhouse gases must satisfy the reasonable requirement that the reduction in emissions can be identified and measured, both at the start of the offset project and during its lifetime. This is necessary in order to ensure that global warming is not worsened by international transfers of entitlements.

- The problem of the uncertain alternative

All transfers of emission entitlements from one country to another presuppose the possibility of determining what the outcome would have been in both countries if trading had not occurred. If the hypothetical question of the size of emissions without offsets cannot be answered with any degree of certainty, fundamental uncertainly arises about the net effects on GHG emission. In that case, these transactions easily become illegitimate.

Only offset activities that go beyond emissions in a well-defined baseline should qualify for entitlements that are transferable. The baseline in this respect should be interpreted as GHG emissions in a business-as-usual world, i.e. a state of the world in which no international offsets take place. Tietenberg (1991) uses afforestation as an example. A CO_2 entitlement should be certified for the amount of CO_2 sequestered in addition to the amount of tree planting that would have commenced in any case. However, a country could maintain that it was planning to cut down all its forest even if this was not its real intention. This underlines that, unless business-as-usual (without offsets) is clearly defined, the introduction of transferable entitlements could give incentives for counterproductive strategic behaviour.

Quantifying the net effect of projects to reduce GHG emissions with a reasonable degree of certainty can, however, be very difficult. It is not always easy to establish whether offset projects are additional to activities that would have taken place in any case. In answering this question, it is not always enough to evaluate the project concerned. Other factors (politics, industrial development, etc.) will determine the total effect of, for example, improvements in the efficiency of a coal-fired power plant. Increased efficiency would reduce emissions and increase economic growth, hence stimulating demand for electricity. In the extreme case, increased growth in demand outweighs the initial emission reduction. This paradox is outlined in Hansen and Haavelmo (1991). They point to the fact that increased efficiency of the economy would normally stimulate economic growth and thereby increase overall emissions.

- Control by a third party

It is also a precondition that the GHG reductions should be verifiable by a third party, among others, governments, green non-governmental organizations (NGOs), and the CH in its capacity as an international control mechanism. An essential requirement in this regard is transparency as regards the information transmitted from the offset investor to national environmental protection agencies (EPAs) as well as from national authorities to the international CH. Furthermore, it is important for all guidelines and the methodology applied to assess emission reductions in each offset project to be made publicly available.

- The legal responsibility of governments

International offsets involve, by definition, transfers of national entitlements for which only the governments are responsible. Thus, even if the offsets are undertaken between private companies or organizations in different countries, the governments must assume full responsibility with respect to the greenhouse Convention.

In this sense, the governments of the countries concerned will normally become involved as "guarantors" for the agreement even if trade is undertaken between private parties. Consequently, it seems reasonable to believe that the governments will demand full information on the transaction as well as the possibility of controlling its effects and will reserve the right to withdraw approval of the agreement if it does not work as intended.

- Distribution of benefits and environmental risk

If international offsets are found to be feasible, they could lead to a substantial gain in the form of reduced abatement costs. It is

important to clarify whether this gain should benefit the involved parties or "the environment" in the form of reduced emissions. If the purchasers of emission entitlements are not to be credited with the whole reduction in emissions arising from the offset project, then offsets would lead to a net reduction in emissions of greenhouse gases. If the price of the GHG entitlement equals marginal abatement cost in the country selling entitlements and the importing country is credited with the whole reduction, the benefit of trade would accrue to the buyer, and the contrary would occur when the price of the entitlement is set equal to marginal abatement costs in the country buying entitlements.

When the net effect on emissions is difficult to assess (owing to the problem of the uncertain alternative or for other reasons), one solution might be to incorporate a safety margin to ensure that the expected environmental effect is neutral or positive. In this case it is necessary to assess on a project-by-project basis the share of the calculated reductions in emissions to be credited to the purchaser. (Under the United States Clean Air Act, in order to be allowed to transfer emissions between two sources (so-called "netting") reductions must be greater than initial emissions).

Market power

As long as the number of actors is limited and fairly influential in determining the outcome of the market, there is a potential problem of market power. Tietenberg (1991) distinguishes between power to manipulate prices of entitlements and power to influence prices in related commodity markets in a way that transfers the scarcity rent from entitlements to other prices. Even if the number of participants in an international trade in entitlements is limited, it will probably be difficult for individual countries to manipulate the market openly in a way that serves their own interests. It is important to remember that governments are directly involved in this trade, and actions by one government to manipulate prices would no doubt be regarded as being unfriendly and in conflict with the acceptable code of conduct for the relations between governments. Furthermore, participation in this market is voluntary. If some governments abuse their market power, others will always have the possibility to withdraw.

In Berger *et al.* (1991), it is suggested that OPEC, by raising the price of oil, could reduce CO_2 emissions sufficiently to reach the emission target that the emission entitlements were introduced to achieve. In that case, the price of entitlements would drop to zero and the rent that would otherwise accrue to entitlement holders would be transferred to oil producers. In theory this is possible. However, by studying OPEC's ability to administer the oil market over the last two decades, it does not seem very likely that the cartel would be successful in rigging the world "CO_2 market". OPEC's market share in the crude oil market is substantial, but even so hardly large enough to manage the market very efficiently. Its corresponding share of the global "CO_2 market", however, is much smaller. Thus its market power in the "CO_2 market" is less significant.

Developing countries have expressed their concern that a group of powerful developed countries might monopolize available entitlements, when the global emissions target is allocated to countries. The fear is that the industrialized countries might "buy up" a large share of emission entitlements at an early stage when these are cheap. At a later stage when entitlements become more expensive, this could severely limit developing countries' ability to grow. This problem is a reflection of the distributional and equity issues involved in the allocation of quotas to countries and the adjustment of these over time. However, ***this is not an issue when it comes to offset investments***. Offsets involve developing countries on a purely voluntary basis. Consequently, offsets can only operate if they are attractive to the host country.

An argument against offsets involving governments that are not part of a greenhouse Convention, or have not committed themselves to a national emission target, has been that it would discourage governments from participation at a later date. As long as they do not accept responsibility, they can sell offsets and thereby generate income and gain access to technology. By joining the agreement, the argument goes, this "free lunch" will disappear. This argument is valid in the sense that the resources generated by offsets in some sense represent a lower threshold to the resources that will have to be made available to these countries to persuade them to join the Convention. However, it is generally accepted that transfers of financial resources and technology will be a feature of any agreement with widespread participation. Furthermore, this kind of side payment will have to benefit developing countries and be paid by developed countries. Thus, offsets could be regarded as the first move in this direction.

B. A market-maker for offset investments

1. *A bourse or a market-maker?*

It is important to distinguish between the role of establishing the framework for a ***market-place*** (i.e. a bourse like the New York Mercantile Exchange) and the role of ***a market-maker***. A precondition for the establishment of a market-place for trade in GHG entitlements that complies with international law is that transactions are undertaken in an orderly way, and in accordance with the basic rules and regulations of the Convention. For this to be the case, the offsetting investments involved need to meet certain criteria with respect to verifiable GHG reductions; they must be monitored by an international and independent body and some sort of compliance mechanism has to be established.

A more ambitious plan would be to establish a CH that should itself identify, appraise and develop projects that reduce GHG emissions, and then fund these activities by selling parts of the emission reductions as entitlements to interested parties. In this case, the CH would not only organize the market-place and set the rules and guidelines that would determine whether a project is eligible for international trade, but would also be responsible for creating the market, i.e. be a market-maker.

The need for the CH to take a more activist role is supported by the experience in the United States that it is difficult to establish a market that performs well in emission entitlements. Tietenberg (1991a) states that, rather than establishing a vigorous market with well-defined prices, emission trading and transferable allowance programmes provide for negotiated agreements between sources, which are supervised and approved on a case-by-case basis by regulatory agencies. There are a number of obstacles to the development of an active market. A limited number of transactions occur simultaneously, transactions costs are considerable and the uncertainty and risks associated with the regulatory framework and the behaviour of the regulatory agencies all reduce the liquidity and efficiency of the market. For these and other reasons, severe limitations have been observed in existing markets for emission entitlements all over the world. Trade is conducted in terms of negotiations and bargaining between buyer and seller and is closely supervised by government agencies.

Potential buyers of international offsets are faced with considerable uncertainty and risks with respect to the way the system will work, the amount of emission credits that will be generated by a specific project, possible future changes in rules and conditions, and so on. Altogether, it seems safe to assume that trade will develop gradually over a number of years. One reason for establishing a market-maker could be to speed up this process.

2. *The developing world and the market-maker*

Concerns about fairness and efficiency are fundamental to any solution to the problem of global warming. A combined system of national emission targets and transferable emission entitlements between countries allows, in principle, both distributional and cost efficiency goals to be pursued at the same time. National emission entitlements distribute abatement costs between countries. Trade in entitlements ensures that abatement projects are implemented where costs are lowest. Thus, one way of preventing developing nations from being made the major victims of a greenhouse agreement is to allocate to them a "fair share" of the earth's capacity to absorb GHG, and to let developed countries buy emission entitlements in exchange for technology and financial resources crucial for their long-term development.

The CH could be introduced as a mechanism to help to bridge the gap between efficiency and equity. In that case, it would not merely perform the task of organizing the market-place for other actors wanting to buy or sell entitlements, but could actively stimulate activities that reduce emissions of GHGs in developing countries and offer the corresponding GHG entitlements to developed countries. The revenues from the entitlements could finance projects and finan-

cial transfers that are necessary to persuade the developing world to participate in the greenhouse agreement.

3. *The role of the market-maker*

The market-maker should be responsible for identifying and appraising projects that are suitable for international offset investments and for issuing licences that quantify the emission reductions with which the investor should be credited. The market-maker should cooperate closely with other international agencies. One alternative is to establish a close link between the CH and the Global Environmental Facility (GEF) in the World Bank. One of the aims of the GEF is to identify and fund projects that reduce emissions of GHGs, but are not profitable from a national point of view when global environmental concerns are disregarded. The idea is that the GEF should finance the extra costs imposed on a project to reduce emissions of GHGs in addition to what is profitable for the investor. Funding is available for projects in developing countries and Eastern Europe.

The CH or a similar crediting system could prove to be a potent funding mechanism to support these kinds of activities. By offering GHG entitlements for sale to countries where abatement costs are high, substantial financial resources and transfers of technology could be made available to countries that are not likely to be part of the Convention or cannot be expected to afford large-scale programmes to curb emissions. If the main aim of the CH is to stimulate activities related to the GEF, consideration could even be given to merging the two by expanding the role of the latter. In that case the GEF should be authorized to certify transfers of emission entitlements between countries. Then there would be no real need for a separate CH.

In its first and rudimentary form, one possibility might be to allow the GEF to initiate projects that reduce GHG emissions, and then to sell parts of the emission reductions involved to governments that are unable to meet their emission targets or where abatement costs are substantially higher. Green NGOs could also buy emission entitlements and thereby reduce global emissions. The revenue from this activity should accrue to the GEF and be used to support soft loans to future projects reducing GHG emissions. One advantage of this arrangement is the fact that transactions would be contained within a multilateral framework and thus be transparent. The scope for trade distortions or counterproductive strategic behaviour on the part of governments that buy offsets or sell entitlements would be reduced. Similarly, the need for measurements and verifications of emission reductions would be manageable and the staff and competence needed to appraise and manage these projects would, by and large, be available within the World Bank.

C. Conclusions and recommendations

1. *Negotiating a system of international offsets*

The crediting system/CH should be negotiated parallel to and as part of the Framework Convention for several reasons:

- Only if this is negotiated simultaneously with the Convention will it be possible to link questions related to equity (i.e. each party's obligation to limit emissions) with the question of efficiency. It is important to negotiate both issues at the same time to persuade developing countries to participate and to introduce flexibility into the national emission targets adopted by developed countries.
- Transfers of entitlements between countries are a novelty and could prove controversial. Hence, including the crediting system in the Convention would enhance its credibility and legitimacy.
- There seems to be a general consensus that the greenhouse problem is not solvable in the long term if reliance has to be placed solely on national abatement strategies and pro rata or other mechanically determined reductions in emis-

sions. More advanced and flexible international environmental agreements have to be developed. Trading is one step in this direction - probably the most promising one. However, the development of new institutions and international practices in this area takes time. Thus, it is important that the Framework Convention should start to move towards policy tools that are likely to constitute an integral and important part of the next generation of international environmental agreements.

A separate body is needed to undertake the task of organizing and supervising international offsets and at a later stage to oversee international trade in entitlements. This body should draw on the experience of other international agencies such as UNEP, UNDP, GEF/WB and IEA when it comes to the kind of expertise that is necessary to assess, develop and implement offsets and evaluate their effect on emissions. However, the crediting system/CH should itself be responsible for recording transactions, developing guidelines and criteria for acceptance, and establishing routines to monitor and control compliance with the rules. It should also have the final authority to accept, or refuse to accept, that a project is liable for offsetting emissions in another country. To establish the necessary acceptance for international offsets, it is imperative for this process to be as transparent as possible. This holds good in particular for the guidelines to be adopted and the information assembled as part of the monitoring and control phase of a project. In addition to close cooperation with selected international bodies, the crediting system will have to base its rulings and control on national environmental protection agencies in the countries involved.

The basic part of the crediting system is obviously the market institution itself. The clearing house naturally consists of an information system and an auction procedure. The information system records information about all potential offsets and all projects that have passed the CH review process and have been accepted. The auction system is a set of rules that establishes procedures for how projects are offered for sale by potential sellers to potential buyers. It is important in this regard to establish procedures that facilitate bilateral transfers of entitlements negotiated between two parties and their gradual development into a market for entitlements.

Finally, it may be appropriate to assign to the crediting system (i.e. the CH) or another international body (the GEF for example) the role of market-maker in the sense that offset projects are actively developed. Identifying and appraising offset projects will, at the outset, be a very demanding task. If undertaken by a well-established agency and/or in close cooperation with the body responsible for developing the general guidelines and principles to be applied to the transfer of entitlements between countries, the process of trial and error could probably be significantly reduced. In the initial phase, international offsets would probably have a good start if they were nourished by an international agency that could act as a guarantor for and give legitimacy to the transactions.

2. *Short-term actions - long-term solutions*

The ongoing preparations and negotiations for the 1992 United Nations Conference on Environment and Development should be regarded as the beginning of a long and complex process. Global greenhouse abatement will be on the agenda for decades. Each country's targeted level of GHG emissions can and probably will be adjusted over time. The policy measures likely to be adopted to curb emissions will change domestically as well as internationally. Thus, it is important to adopt strategies in which short-term actions are the first steps towards the solutions that are desirable in the long term. To be more precise, short-term actions to establish a crediting system for regulating bilateral agreements between two countries, or multilateral institutions to limit emissions cooperatively and to oversee offset investments, should be regarded as the first steps towards a global system of tradeable GHG emission entitlements.

In this first phase, an important objective is to establish an institutional framework that will allow emission entitlements to be transferred between countries, and to define the commodities to be traded through bilateral offset investments. At this stage, transfers of entitlements will have to be closely supervised by an international body - referred to in this chapter as a crediting system or clearing house. Furthermore, the transition to a more advanced system of international trade in entitlements could be speeded up if the clearing house and/or the GEF act as a market-maker, i.e. actively developing offset projects.

Both well-established market institutions and clearly defined commodities to be traded are preconditions for the next evolutionary step. In the second phase, the number of buyers and sellers of offsets will increase because private sector participation will be encouraged and emission entitlements will be stored through emission banking. The number of transactions will increase and improve the liquidity and transparency of the embryonic market for emission entitlements.

Finally, a well-organized international market (i.e. bourse), open to universal participation, should develop. Buyers and sellers will become numerous and anonymous, and trade will be undertaken in physical emission entitlements as well as in paper markets. Governments will trade in this market alongside private companies. However, even at this stage, the regulatory framework will differ between countries. Some will rely on tradeable emission entitlements in their domestic GHG abatement strategy, while others will depend on command and control measures or will tax emissions. In countries with a system of domestically tradeable emission quotas, private firms could trade freely both domestically and on the international market. In a different regulatory environment, governments might choose to limit the number of traders to a greater extent.

As has been indicated before, the number of signatories to an international greenhouse agreement is likely to be somewhat limited at the outset. This seems particularly likely in the case of national commitments to limit emissions to specific levels. However, it is very important that participation should be as comprehensive as possible. International offsets are of special importance in this respect because they increase the attractiveness of participation for the developing world. Emission reductions should be expected to be relatively low in developing countries and countries in transition. Thus, these countries are attractive for offset investments. On the other hand, offsets could be traded for access to technology and capital, which are vital for economic growth and development.

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Chapter IV

RELEVANT EXPERIENCE WITH TRADEABLE ENTITLEMENTS

Tom Tietenberg*

Introduction

One useful point of departure for crafting a tradeable entitlement approach to controlling greenhouse gases is provided by the lessons derived from existing applications of this economic incentive approach. Though the translation of these experiences from their purely national settings to the international setting will not be simple, the lessons are instructive. They help to clarify the key design issues and to avoid potential pitfalls by anticipating and resolving them.

The tradeable entitlement or permit approach to pollution control was first introduced in the United States where it has received its most vigorous application up to date. Beginning in 1975, burgeoning costs associated with the rigidities inherent in its traditional, predominantly legal, approach to controlling air pollution led the United States Environmental Protection Agency (EPA) to begin experimenting with a transferable permit approach now known as the Emissions Trading Program. Since that time the tradeable entitlement (permit) concept has been applied to several new areas of environmental policy and is currently being proposed for several more.

Support for the use of this market approach to environmental control has clearly grown in the United States, as reflected in the favourable treatment it has received both in the popular business[1] and environmental[2] press. Some public interest environmental organizations have even adopted tradeable entitlement approaches as a core part of their strategy for protecting the environment.[3] As described below this entitlement approach is also spreading to other nations.

Our knowledge about tradeable entitlements has grown rapidly during the last two decades in which it has received serious analytical attention. Not only have the theoretical models become more focused and the empirical work more detailed, but we have now had over a decade of experience with several limited but operational versions of this approach. It seems a propitious time to stand back and to organize what we have learned about this practical and promising approach to pollution control.

This chapter draws upon economic theory, empirical studies, and actual experience with implementing the various versions of tradeable entitlement programmes to provide

* Department of Economics, Colby College, Waterville, Maine.

1 See, for example, Main (1988).

2 See, for example, Stavins (1989).

3 See the various issues in volume XX of the *EDF Letter*, a report to members of the Environmental Defense Fund.

a brief overview of some of the major lessons that are instructive in crafting a similar approach tailored to the control of greenhouse gases.[4] Some of the proposed extensions to new settings will also be discussed in order to suggest the range of applicability.

A. Current experience

1. *Transboundary application*

The ozone shield in the stratosphere protects humans from harmful ultraviolet radiation. Current evidence suggests that this shield is being depleted by man-made chemicals such as chlorofluorocarbons and halogens, and the resulting increase in ultraviolet rays raises the incidence of both skin cancer and damage to eyesight. These gases also contribute to global warming.

Responding to this threat, 24 nations signed the Montreal Protocol in September 1988. According to this agreement signatory nations have to restrict their production and consumption of the chief gases responsible to 50 per cent of 1986 levels by 30 June 1998. In one of the provisions of the agreement, production quotas are transferable both within and between nations. Since transferable production quotas have some similarities in design and concept to transferable carbon dioxide entitlements, this is an important international precedent.

2. *Applications in the United States*

(a) *Conventional air pollutants*

Stripped to its essentials, the foundation of the United States approach to pollution control is based upon a traditional command-and-control regulatory system. Ambient standards, which establish the highest allowable concentration of each conventional pollutant in the ambient air or water, represent the targets of this approach. To reach these targets, emission or effluent standards (legal discharge ceilings) are imposed on a large number of specific discharge points such as stacks, vents, outfalls or storage tanks. Following a survey of the technological options of control, the control authority selects a favoured control technology and calculates the amount of discharge reduction achievable by that technology as the basis for setting the emission or effluent standard. Technologies yielding larger amounts of control (and, hence, supporting more stringent standards) are selected for emitters in areas where it is very difficult to meet the ambient standard and also for new emitters. The responsibility for defining and enforcing these standards is shared in legislatively specified ways between the national government and the various state governments.

In an attempt to inject more flexibility into the manner in which the objectives of the Clean Air Act were met during the last half of the 1970s, the United States EPA created what has now become known as the Emissions Trading Program. The programme attempts to facilitate compliance by allowing sources a much wider range of choice in how they satisfy their legal pollution control responsibilities than is possible under the command-and-control approach. Any source choosing to reduce emissions at any discharge point to a greater extent than required by its emission standard can apply to the control authority for certification of the excess control as an "emission reduction credit" (ERC). Defined in terms of a specific amount of a particular pollutant, the certified emission reduction credit can be used either to satisfy emission standards at other discharge points (presumably more expensive to monitor) controlled by the creating source, or it can be sold to other sources. By making these

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4 In the limited space permitted by this chapter only a few highlights can be illustrated. All the details of the proofs and the empirical work can be found in the references listed at the end of the chapter. For a comprehensive summary of this work see Tietenberg (1980), Tietenberg (1985), Dudek and Palmisano (1988) and Hahn and Hester (1989).

credits transferable, the EPA has allowed sources to find the cheapest means of satisfying their requirements, even if the cheapest means are under the control of another firm. The ERC is the currency used in emissions trading, while the offset, bubble, emissions banking and netting policies govern how this currency can be stored and spent.[5]

The offset policy requires major new or expanding sources in "nonattainment" areas (those areas with air quality worse than the ambient standards) to secure sufficient offsetting emission reductions (through the acquisition of ERCs) from existing firms to make the air cleaner after their entry or expansion.[6] Prior to this policy no new firms were allowed to enter nonattainment areas on the grounds that they would interfere with the attainment of the ambient standards. By introducing the offset policy, EPA allowed economic growth to continue while ensuring progress towards attainment.

The bubble policy receives its unusual name from the fact that it treats multiple emission points controlled by existing emitters (as opposed to those expanding or entering an area for the first time) as if they were enclosed in a bubble. Under this policy only the total emissions of each pollutant leaving the bubble are regulated. While the total leaving the bubble must be no larger than the total permitted by adding up all the corresponding emission standards within the bubble (and, as a result of recent changes in the rules, must be 20 per cent lower), emitters are free to control some discharge points less than dictated by the corresponding emission standard as long as sufficient compensating ERCs are obtained from other discharge points within the bubble. In essence, sources are free to choose the mix of control among the discharge points as long as the overall emission reduction requirements are satisfied. Multi-plant bubbles are allowed, opening the possibility for trading ERCs among very different kinds of emitters.

Netting allows modifying or expanding sources (but not new sources) to escape from the need to meet the requirements of the rather stringent new source review process (including the need to acquire offsets), so long as any net increase in emissions (counting any ERCs earned elsewhere in the plant) is below an established threshold. In so far as netting allows firms to escape particular regulatory requirements by using ERCs to remain under the threshold that triggers applicability, it is more properly considered regulatory relief than regulatory reform.

Emissions banking, the final component, allows firms to store certified ERCs for subsequent use in the offset, bubble or netting programmes or for sale to others. The banking component provides key institutional support for the programme by serving as an easily accessible storehouse of credits available for sale, and as a means of facilitating trades when demand and supply in respect of credits are not perfectly synchronized.

(b) Lead in gasoline

Since the inception of the Emissions Trading Program, the marketable entitlement concept has been applied in a number of new and rather different areas, demonstrating its versatility. One of those applications involved a programme to facilitate a rapid transition to the widespread availability of unleaded gasoline.

In the month prior to the issuance of new and more stringent regulations on lead in gasoline, EPA announced the results of a cost-benefit analysis of their expected impact. The analysis concluded that the proposed standard of 0.01 grams per leaded gallon (gplg) would result in $36 billion (1983 dollars) in benefits (from reduced adverse health effects), at an estimated cost to the refining industry of $2.6 billion. The regulation was unquestionably justified on efficiency grounds.

A main concern of EPA in issuing these regulations was the rigidity of the intermediate deadlines used to implement the phasedown. While some refiners could meet early deadlines with ease, others could do so only at a significant increase in cost. Recognizing that meeting the goal did not require every refiner to meet each deadline, EPA initiated the lead banking programme to provide additional flexibility in complying with the regulations.

While not a part of the Emissions Trading Program discussed above, the lead bank-

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5 The details of this policy can be found in "Emissions trading policy statement" 51 *Federal Register* (4 December 1986):43829. This document is based upon a decade of experience with the programme. For a description of its evolution see Tietenberg (1986).

6 Offsets are also required for major modifications in areas that have attained the standards if the modifications jeopardize attainment.

ing programme did share some design similarities with it. Under this programme, refiners reducing lead more than required by the applicable standard in each quarter of the year could bank the credits for use or sale in some subsequent quarter. Banked credits were fully transferable among refiners.

The lead banking programme, though plagued by less-than-perfect implementation procedures, eased the transition to the new and more stringent regulatory regime.[7] Refiners had an incentive to respond quickly because reductions in lead undertaken prior to the deadlines became valuable under the new programme. Acquiring these credits made it possible for other refiners to comply with the deadlines, even in the face of equipment failures or Acts of God; fighting the deadlines in court - the traditional response - was no longer necessary. Designed purely as a means of facilitating the transition to this new regime, the lead banking programme ended as scheduled on 31 December 1987.

The lead banking programme shows how marketable entitlement systems can be used to facilitate the transition to more strict regulatory regimes. By providing more flexibility coupled with incentives for meeting the deadlines early, it respected differences in the capabilities of polluters to meet stringent deadlines without sacrificing the overall environmental objectives. Since deadlines will be an essential part of any international approach to controlling global warming, this is a useful attribute.

(c) Ozone-depleting chemicals

On 12 August 1988 the United States Environmental Protection Agency issued regulations implementing a marketable permit system to achieve the United States targeted reductions.[8] According to these regulations all major United States producers and consumers of the controlled substances were allocated baseline allowances for which 1986 levels were used as the basis for the pro rata calculations. Each producer and consumer is allowed 100 per cent of this baseline allowance for each year before 1 July 1993, 80 per cent between 1 July 1993 and 30 June 1998 and 50 per cent after 30 June 1998. These allowances are transferable within producer and consumer categories. Production allowances can be transferred across international borders to producers in other signatory nations provided that the transaction is approved by EPA and results in the appropriate changes in the buyer's and seller's production allowances in their respective countries. Production allowances can be augmented by demonstrating the safe destruction of an equivalent amount of controlled substances by approved means, but so far no means have been approved.

Though the EPA chose to allocate the production allowances on the basis of historical levels of use, it was clearly uneasy about this choice.[9] Since the demand for these allowances is quite inelastic, supply restrictions increase revenue. By allocating allowances to the seven major domestic producers of CFCs and halons, EPA was concerned that its regulatory action would result in sizeable windfall profits (estimated to be in the region of billions of dollars) for those producers. It was further concerned that the existence of these windfalls would create an economic incentive for producers to delay the introduction of more environmentally benign chemical substitutes.

Confronted with scientific evidence that the reduction in CFC use, mandated by the Montreal Protocol, might not be sufficiently stringent, concerned about the excess profits to which the allowance holders would be entitled and seeking new sources of revenue to counteract a growing budget deficit, the United States Congress complemented this marketable permit or entitlement approach with a special tax on ozone-depleting chemicals.[10] The amount of the tax per pound of the chemical sold or used is equal to a base tax multiplied by an "ozone-depleting factor" specific to each chemical. These factors range from a low of 0.8 for CFC-113 to 10.0 for

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7 For some of the details of the programme as well as a description of some of the implementation difficulties, see Nussbaum (1991).

8 53 *Federal Register* 30598 (12 August 1988). The final rules governing transfer of import and production allowances are in 54 *Federal Register* 6376 (9 February 1989). These rules have been consolidated in 40 *Code of Federal Regulations* 82.

9 When issuing the rules for the ozone depletion gas permit system, EPA sought public comment on the possibility of ultimately replacing its free distribution of permits on the basis of historical use by an auction market. Though EPA never followed up on this possibility (a tax was imposed instead), it demonstrates a recognition of, and concern for, the wealth effects inherent in a restrictive, cost-effective system of pollution control.

10 Ozone-depleting chemicals are defined in the Act as CFC-11, CFC-12, CFC-113, CFC-114, CFC-115, Halon-1211, Halon-1301 and Halon-2402. See 103 Stat 2365.

Halon-1301. The base tax rates rise from $1.37 in 1991 to $2.65 in 1994, with further annual increases of 45 cents each year thereafter.

One of the useful lessons for controlling global warming that is to be drawn from this application is that it demonstrates the complementarity of using transferable entitlements in conjunction with fees. When used together, both are allowed to fulfil the roles for which they are best suited - entitlements produce the desired control of quantities emitted while fees raise revenue.

(d) Water pollution

Virtually all water pollution control policy in the United States has been focused on point sources: large identifiable polluters emitting effluents from specific discharge points. As the controls on point sources have been tightened, nonpoint sources (such as the overflow from urban storm sewers or the runoff from farms) become responsible for a larger share of the remaining pollution. Although nonpoint sources are now responsible for the bulk of the problem that still subsists, they are notoriously difficult to regulate by traditional means.

Because the marginal cost of controlling nonpoint sources is now considerably lower than the marginal cost of securing further reductions from point sources, ways of bringing nonpoint sources under control are of great interest. One result of the attention paid to them has been the introduction of an option to trade waste reduction entitlements between point and nonpoint sources for bodies of water where further control is required.

One example of this approach has occurred in the Lake Dillon Watershed, a primary source of water for Denver, Colorado.[11] Changing land uses and development have produced near-eutrophic algae in the lake, despite the fact that all waste water treatment plants on the lake currently employ advanced methods for phosphorus removal. Even with zero phosphorus discharge from treatment plants in the future, nonpoint phosphorus sources from growth areas would make the lake eutrophic.

Transferable permits (entitlements) were introduced as part of an overall management plan for the lake. According to this plan all waste treatment plants would continue to apply advanced waste water treatment, and state-of-the-art nonpoint source controls would be applied by local governments to all new development projects in the basin. An effluent trading system was developed to accommodate expected source growth beyond 1990 by encouraging reductions for nonpoint sources that existed prior to 1984 and therefore were not subject to the new regulations. Authorized by the State Commission, the trading rules require a 2:1 ratio to account for uncertainties in the process. One pound of waste reduction credit is certified for every two pounds of phosphorus eliminated from pre-existing nonpoint sources. This approach is expected to keep the phosphorus loading at 1982 levels while accommodating expected source growth. It allows local governments to control phosphorus in the most cost-effective manner without being limited to further reductions in point sources.

The nonpoint source application demonstrates how a marketable entitlement system can reduce costs by bringing previously unregulated sources under control. By coupling economic incentives for controlling new sources with procedures forcing traders to bear a rather heavy burden of proof in demonstrating the magnitude and enforceability of the proposed reductions, regulators can spread the control burden over a larger number of sources while assuring the integrity of the process.[12]

(e) Acid rain

A version of the emissions trading concept has also been incorporated into the United States approach for achieving further reductions in pollutants contributing to acid rain from electric utilities.[13] Under this inno-

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11 See Northwest Colorado Council of Governments (1984).

12 As the political forces are gearing up for the periodic reauthorization of the United States Clean Water Act, transferable permits (entitlements) are being discussed in three different contexts. First, significant interest has materialized in generalizing and expanding the point-nonpoint trading approach as illustrated by the Dillon Reservoir case. Second, the use of transferable development rights as a means of protecting wetlands is being discussed. Finally, the possibility of trading responsibilities for pretreating waste entering into publicly owned sewage treatment plans is also being explored. At this stage it is impossible to know which, if any, of these ideas will find their way into the revised law. (This information was gathered by means of a telephone conversation with Dr. William O'Neil, United States Environmental Protection Agency, 7 June 1991.)

13 This title was included in the Clean Air Act Amendments of 1990, which became law on 15 November 1990. See

vative approach allowances to emit sulphur oxides will be allocated to older plants, and the number of allowances will be restricted to assure a reduction of 10 million tons in emissions from 1980 levels. Although these allowances are defined for a specific calendar year and cannot be used prior to that year, the Act contains provisions for carrying unused allowances forward into the next year. Unused allowances are transferable among the affected sources. Any plant reducing emissions more than required by its initial allocation of allowances could transfer the unused allowances to other plants. These acquired allowances can be used by the owners of the purchasing source to ensure that its emissions do not exceed the levels permitted by the allowances (allocated plus acquired) that it holds. The Act even anticipates the possibility of interpollutant trading between sulphur and nitrogen oxides by requesting a study of its feasibility.[14]

Adopting this approach resulted from the Congressional belief that the acid rain reduction goals could be achieved at a much lower cost than would otherwise be possible. Utilities that could afford to reduce their emissions relatively cheaply would do so, selling or leasing any excess reduction to those for whom further reductions would be much more expensive. Both the plants and their customers could be made better off by the allowance transfer. The allowances would go where they could be best used, minimizing the overall cost of control in the process, while the legislatively mandated total emission reduction would be held constant.

The acid rain application is particularly interesting for this study because the acid rain tradeable allowances treat sulphur oxides in the same manner that greenhouse gases would be treated in a global transferable entitlement market designed to control global warming, i.e. tradeable on a one-for-one basis. The expectations of a vigorous market in these acid rain allowances are sufficiently high for a spot market in these allowances to exist already and the Chicago Board of Trade expects to open a forward market for allowances in 1992-1993.[15]

3. *Applications in Germany*[16]

Germany has used a limited form of transferable emission entitlements for a number of years. Under this programme plant operators are allowed to deviate from strict standards, providing that ambient air concentrations are reduced. The first programme (governed by the plant renewal clause) allows new plants seeking to locate in areas where allowable ambient concentrations have been exceeded to acquire emission offsets from the renovation or renewal of old plants; without these compensating reductions the establishment of new plants in these areas would not be allowed. In the second programme authorities can deviate from the new licensing procedure required for plants undergoing renewal, providing greater reductions are achieved from the proposed deviation (including the acquisition of offsets) than would have been achieved from the follow-up order. A unique characteristic of the German programme is that it does not limit the offsetting reductions to the same pollutant; reductions of other pollutants can serve as offsets providing they have comparable effects on the environment.

4. *Applications in Canada*[17]

An intra-utility form of trading (similar to the United States bubble concept) is already allowed in Ontario. The utility involved is required to meet an aggregate emissions cap, but is given great flexibility in how it chooses to fulfil that responsibility.

Canada is currently investigating the use of transferable permits (entitlements) in two new contexts. The first application would

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104 Stat 2584. For an analysis of the application of the emissions trading concept to acid rain, see Atkinson (1983); Raufer and Feldman (1984); Oates and McGartland (1985); Feldman and Raufer (1987); and Tietenberg (1989).

14 104 Stat 2591.

15 Remarks by Mr. Richard Sandor, Chairman of the Clean Air Committee of the Chicago Board of Trade at the UNCTAD Expert Workshop on a Global Scheme for Tradeable Carbon Emission Entitlements, Geneva, Switzerland, 31 October-1 November 1991.

16 Opschoor and Vos (1989).

17 The information in this section was derived from a telephone conversation with Erik Haites, a principal with Barakat & Chamberlin, the consulting firm involved in examining the feasibility of these proposals.

allow the trading of NO_x and VOC credits within each of Canada's three ozone nonattainment areas (Vancouver, Ontario and Quebec, and southern New Brunswick). The second application would involve SO_2 trading.

5. *Applications in Eastern Europe and Asia*

Interestingly the transferable entitlement approach has spread to the less industrialized countries. In crafting its environmental policy for the future, Poland is committed to the introduction of a form of transferable entitlements patterned on the emissions trading system in the United States.[18] This choice was justified on the grounds that transferable entitlements provide a degree of environmental security possible only with a quantity-based system of controls, while offering polluters the flexibility for cost-effective achievement of those goals. Interestingly this choice followed an investigation (and rejection) of emission charges.

According to press reports China has also recently adopted a transferable entitlement system of pollution control to complement its programme of fines for violations of the entitlements, though the details of the system remain sketchy.[19]

6. *A proposed application in the United Kingdom*[20]

The United Kingdom is considering applying a variant of a marketable entitlements approach to promote energy efficiency and pollution control in the transport sector.[21] The basic proposal involves the setting of a fuel efficiency target for manufacturers and importers to achieve in the aggregate from sales of new vehicles. As each new car is registered, it would qualify for a credit if it performed better than a prespecified baseline standard. The credit would be issued to the new car manufacturer or importer by the regulatory authority. Conversely manufacturers or importers would have to deposit sufficient credits to offset the amounts by which new vehicles exceeded the baseline. Credits could be acquired within the company from the rest of the fleet whose performance improved upon the baseline. They could also be purchased from other manufacturers or importers, or acquired from banks where excess credits had been deposited by those who generated them.

One of the interesting characteristics of this system is that it demonstrates how a transferable entitlement market can be implemented even for pollution sources that are small but numerous (such as automobiles). In this case the suggested solution is to apply the programme at the point of production rather than at the point of use. Because the number of producers and importers is small, transactions costs can be kept acceptably small.

7. *Applications other than pollution control*

(a) Fisheries in New Zealand[22]

A quite different application of the tradeable entitlement concept has been used in New Zealand to reduce the stress on an already overexploited renewable resource. Some particularly desirable fish species in New Zealand were being seriously overfished. While the need to reduce the amount of pressure on the fish population was obvious, how to accomplish that aim was not at all clear. Although it was relatively easy to prevent new fishermen from entering the fisheries, it was harder to decide how to induce persons who had been fishing in the area for many years to limit their catch. As fishing is characterized by economies of scale, reducing each person's catch proportionately would not make much sense. It would simply raise everyone's costs and waste a great deal of fishing capacity as boats remained idle for a significant amount of time.

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18 Zylicz (1991).

19 Nadelson (1991).

20 Taylor (1991). The author is a member of the United Kingdom Department of Transport.

21 A similar scheme is now being considered in California. See Stevens (1991). The author of the California report is on the staff of the California Energy Commission.

22 See Campbell (1989) and Pearse (1991).

A better solution would clearly be to have fewer boats harvesting the stock. Each boat could then be used closer to its full capacity without depleting the fish population. The question then is which fishermen should be asked to give up their livelihood and leave the industry?

The tradeable entitlement approach addressed this problem by imposing catch quotas on fishermen for which they had to pay an annual fee. The revenues derived from this fee were used to buy out fishermen who were willing to forgo future fishing for the species in jeopardy. Essentially each one stated the lowest price that would be acceptable for leaving the industry; the regulators selected those who could be induced to leave at the lowest price, paid the stipulated amount from the tax revenues, and withdrew their licence to fish the species concerned. It was not long before a sufficient number of licences had been withdrawn and the population was protected. Since the programme was voluntary, those who left the industry did so only when they felt they had been adequately compensated. Meanwhile, those who paid the fee realized that this small investment would benefit them greatly in the future as the population recovered. Thus, a difficult and potentially dangerous pressure on a valuable natural resource was avoided by the creative use of a tradeable entitlement system.

(b) Milk production quotas in the EC[23]

To reduce the milk surplus produced as a result of price supports, in the mid-1980s every member state in the EC was assigned a production quota based on 1983 milk production minus 8.65 per cent. The milk quotas were tradeable, but the EC Council ultimately decided to restrict their transferability. The quotas were linked to the amount of land that a farmer used for the raising of dairy cattle in the reference year. By acquiring new land or selling currently owned land, the owner buys or sells quotas as well. With some anomalies apparently attributable to the restrictions on transfers,[24] the scheme has reportedly worked well.

B. Lessons

1. *Lessons from theory*

Theory can help us to understand the characteristics of this economic approach in the most favourable circumstances and assist in the designing of the instruments for maximum effectiveness.

(a) *Assuming all participants are cost minimizers, a "well-defined" transferable entitlement market could cost-effectively allocate the control responsibility for meeting a predefined pollution target among the various sources of pollution despite incomplete information on the control possibilities by the regulatory authorities.*

The reasoning behind this theorem is not difficult to grasp. Cost-minimizing firms seek to minimize total entitlement and control costs. Minimization will occur when the marginal cost of control is set equal to the entitlement price. Since all sources will see that their marginal control costs are equal to the same price, an entitlement market will equalize marginal control costs across all discharge points, precisely the condition required for cost effectiveness.[25] In essence,

23 Information supplied by Paul Koutstaal, Faculty of Law, Department of Economics, University of Groningen.

24 Because of the linkage between land and the quota, the system has had some peculiar side-effects that were never intended. For example, farmers in the southern part of the Netherlands, who wanted to enlarge their herds but could not do so because of the quotas, bought land in the northern provinces which they left idle. The quotas linked to this newly acquired land were then used to justify higher milk production in the south.

25 It should be noted that, while the allocation is cost effective, it is not necessarily efficient. It would only be efficient if the predetermined target happened to coincide with the efficient amount of pollution. Nothing guarantees this outcome.

sources needing extra emission reduction, either as a precondition to entering an area or to meet emission standards, can purchase transferable entitlements from sources with the lowest marginal costs of control.

Though derived from the rarified world of theory, the practical importance of this theorem should not be underestimated. Transferable entitlements offer a unique opportunity for regulators to solve a fundamental dilemma. Control authorities usually want to allocate the responsibility for control cost effectively, but they rarely have the information required to achieve this objective. Transferable entitlements create a system of incentives in which those who have the best knowledge about control opportunities - the environmental managers for the industries - are encouraged to use that knowledge to achieve environmental objectives at minimum cost. Information barriers do not preclude effective regulation.

(b) *Transferable permits encourage more technological progress in pollution control than the command-and-control system.*[26]

Traditional command-and-control policies usually base standards on technologies known to the regulators. Meeting those standards can be accomplished simply by adopting the identified technology. Adopters have little incentive to search for superior technologies.

With transferable entitlements, adopters have an incentive not only to search for new technologies that reduce the cost of compliance with the mandated standard, but also to search for technologies that can reduce emissions more than required by the standard. Selling the emission reduction credits (or unused allowances) produces revenue which can be used to finance the new technologies. Entitlements allocated on the basis of past emissions provide fewer incentives for technological progress than either emissions charges or auctioned entitlements, but more incentives than a command-and-control system.

(c) *What constitutes a "well-defined" transferable entitlement system depends crucially on the attributes of the pollutant being controlled.*[27] *Fortunately, the category containing greenhouse gases is the simplest to design and implement.*

To be consistent with a cost-effective allocation of the control responsibility, the entitlements would have to be defined in different ways for different types of pollutants. Three differentiating characteristics have been identified in the literature so far. First, entitlements designed to control pollutants that are uniformly mixed in the atmosphere (such as CFCs) can be defined simply in terms of a rate of emissions flow per unit of time. Secondly, entitlements to control pollutants (such as heavy metals) that build up in the environment over time would be defined in terms of a stock of emissions rather than an emissions flow. Lastly, entitlement design becomes quite complicated when the pollution target pursued is defined in terms of concentrations (such as sulphur oxides or particulates) measured at a number of specific receptor locations. In this case it would be necessary for the cost-effective design to take into account the location of the emissions (including injection height) as well as the amount of emissions. As greenhouse gases can be treated as falling within the first category, designing the entitlement is easiest for this type of pollutant.

(d) *As long as markets are competitive and transactions costs are low, the trading benchmark in an emissions trading approach does not affect the ultimate cost-effective allocation of control responsibility. When markets are non-competitive or transactions costs are high, however, the final allocation of control responsibility is affected.*[28]

Once the control authority has decided how much pollution of each type will be allowed, it must then decide how to allocate the entitlements among the sources. In theory, entitlements can either be auctioned off, with the sources purchasing them from the control authority at the market-clearing price, or allocated among existing sources free of charge based on some regulatory distribution rule. The premise suggests that either approach will ultimately result in a cost-effective allocation of the control responsibility among the various polluters as long as they are all price-takers, transactions costs are low, and the entitlements are freely transferable. Even when they are randomly distributed without cost among existing sources, the after-market

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26 Milliman and Prince (1989).

27 For the technical details supporting this proposition, see Montgomery (1972), Palmer *et al.* (1980) and Tietenberg (1985).

28 See Hahn (1984) for the mathematical treatment of this point. Further discussions can be found in Tietenberg (1985) and Misiolek and Elder (1989).

in which firms can sell excess entitlements and purchase additional ones corrects any problems with the initial allocation. This is a significant finding because it implies that under the right conditions the initial allocation can be used to pursue distributional goals without interfering with cost effectiveness. This is a particularly noteworthy characteristic in view of the possibility of incorporating transfers to developing countries in any permanent solution to the global warming problem.

When firms are price-setters rather than price-takers, however, cost effectiveness will only be achieved if the control authority initially allocates the entitlements in such a way that a cost-effective allocation would be achieved even in the absence of any trading. For all other initial entitlement distributions an active market would exist, offering the opportunity for price-setting behaviour. The larger the deviation of the initial allocation of entitlements to a single price-setting source the greater the likelihood that the source in question can exercise market power.[29]

Similar problems exist when transactions costs are high, since these can preclude or reduce trading by diminishing the gains from trade. When the costs of concluding the transaction exceed the potential gains, the incentive to participate in the market is lost.

2. *Lessons from empirical research*

(a) *A vast majority, though not all, of the relevant empirical studies have found that control costs are substantially higher with the regulatory command-and-control system than the least cost means of allocating the control responsibility.*[30]

While theory tells us unambiguously that the command-and-control system will not be cost effective except by coincidence, it cannot tell us the magnitude of the excess costs. The empirical work adds the important information that the excess costs have typically been very large. This is an important finding because it provides the motivation for introducing a reform programme; the potential social gains (in terms of reduced control cost) from breaking away from the status quo are sufficient to justify the trouble. Although the typical estimates of the excess costs attributable to a command-and-control system overstate the cost savings that would be achieved by even a completely unrestricted entitlement market (a point discussed in more detail below), the general conclusion that the potential cost savings from adopting market-based approaches are large remains accurate even after correcting for overstatement.

(b) *Only a transferable entitlement system that allocates entitlements free of charge to sources on the basis of their historical emission rate would guarantee that existing sources would be no worse off than they would under a command-and-control system imposing the same degree of control. The financial outlays associated with acquiring allowances or ERCs in an auction market (or a comparable emissions charge) would be large enough for sources typically to have lower financial burdens with the traditional command-and-control approach than with these particular economic incentive approaches.*[31]

From the point of view of the source required to control its emissions, two components of the financial burden are significant: (1) control costs and (2) expenditures on entitlements. While only the former represent real resource costs to society as a whole (the latter are merely transferred from one group in society to another), to the source both represent a financial burden. The empirical evidence suggests that when an auction market is used to distribute entitlements (or, equivalently, when all uncontrolled emissions are subject to an emissions tax), the entitlement expenditures (tax revenue) would frequently be larger in magnitude than the control costs. The sources would spend more on entitlements (or pay more in taxes) than they would on the control equipment.

Under the traditional command-and-control system firms make no financial out-

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29 When a price-setting source is initially allocated more than its cost-effective allocation, it can inflict higher control costs on others by withholding some entitlements from the market. However, when a price-setting source is initially allocated fewer entitlements than would be justified by its cost-effective responsibility, it can exercise power on the buyer side of the market.

30 These studies are surveyed and compared in Tietenberg (1985).

31 See Atkinson and Tietenberg (1982), Atkinson and Tietenberg (1984), Hahn (1984), Harrison (1983), Krupnick (1986), Lyon (1982), Palmer *et al.* (1980), Roach *et al.* (1981), Seskin *et al.* (1983) and Shapiro and Warhit (1983) for the individual studies, and Tietenberg (1985) for a summary of the evidence.

lays to the government. Although control costs are necessarily higher with that system than with a marketable entitlement system, they are not so high as to outweigh the additional financial outlays required in an auction market entitlement system (or an emissions tax system). For this reason existing sources understandably oppose the distribution of entitlements by an auction market despite its social appeal, unless the revenue derived is used in a manner that is approved by the sources, and the sources with which they compete are required to absorb similar expenses.

(c) *While it is clear in theory that larger trading areas and larger numbers of traders offer opportunities for larger potential cost savings in a transferable entitlement programme, some empirical work suggests that substantial savings can be achieved even when the trading areas and the number of potential trades are rather small. This is an important point because it suggests that even very limited steps towards a transferable entitlement system could be beneficial.*

Sometimes political considerations mandate a limited transferable entitlement programme. Whether large trading areas and large numbers of traders are essential for the effective use of this policy is, therefore, of some relevance. The amount of cost savings achieved by any entitlement market would be a function of the size of the area within which the entitlements may be traded and of the number of traders. In general, larger trading areas and larger numbers of traders increase the potential cost savings owing to the wider set of cost-reduction opportunities made available. The empirical question is how sensitive the cost estimates are to these components.

One study of utilities in the United States has found that even allowing a plant to trade among discharge points within that plant could save 30 to 60 per cent of the costs of complying with new sulphur oxide reduction regulations, compared to a situation in which no trading whatsoever was permitted.[32] Expanding the trading possibilities to other utilities within the same state permitted a further reduction of 20 per cent, while allowing interstate trading permitted another 15 per cent reduction in costs. If this study is replicated in other circumstances, it would appear that even small trading areas offer an opportunity for significant cost reduction.[33]

(d) *Although only a few studies of the empirical impact of market power on the cost effectiveness of transferable entitlement markets have been carried out, their results are consistent with a finding that market power does not seem to have a great effect on regional control costs in most realistic situations.*[34]

Under favourable circumstances for the exploitation of market power, the available evidence suggests that, while price manipulation in auction entitlement markets could have a fairly large impact on the regional financial burden, under normal circumstances its effect on control costs would be rather small. Estimates typically suggest that control costs would rise by less than 1 per cent if market power were exercised by one or more firms.

The effects of market power depend on whether the entitlements are distributed by auction or are free of charge. In an auction market the price-setting source reduces its financial burden by purchasing fewer entitlements than otherwise in order to drive the price down. To compensate for the smaller number purchased, the price-setting source must spend more on controlling its own pollution, thereby limiting the gains from price manipulation.

With regard to free distribution rules, some rules create a larger potential for strategic price behaviour than others. In general the larger the divergence between the number of entitlements received by the price-searching source and the cost-effective number of entitlements, the greater the potential for market power. When allocated an excess of entitlements by the control authority, price-searching firms can exercise power on the selling side of the market, and when allocated too few entitlements, they can exercise power on the buying side.

According to the existing studies it takes a rather considerable divergence from the cost-effective allocation of entitlements to produce a significant difference in regional control costs. Since most realistic rules used to distribute entitlements are estimated to affect control costs to such a small degree, the

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32 ICF, Inc. (1989).

33 As indicated below, the fact that so many emissions trades have actually taken place within the same plant or among contiguous plants provides some confirmation of this result.

34 For individual studies see de Lucia (1974), Hahn (1984) and Maloney and Yandle (1984). For a survey of the evidence see Tietenberg (1985).

deviations from the least cost allocation caused by market power pale in comparison to the much larger potential cost reductions achievable by implementing a transferable entitlements system.[35]

3. Lessons from implementation

Although comprehensive data on the effects of the various transferable entitlement programmes do not exist because the relevant information has not yet been collected in a systematic way, some of the major aspects of the experience are clear.

(a) *The transferable entitlement programmes in the United States have evolved considerably since their inception in the 1970s. Starting with a very limited system which only remotely resembled the theoretical concept, the programmes have evolved to the point where the newest programme - acid rain allowances - is expected to approximate a transferable entitlement market rather closely.*

Rather than establishing a vigorous market with well-defined prices as envisioned by early proponents, the early emissions trading programme involved negotiated trades between sources, individually supervised and approved by regulatory agencies on a case-by-case basis. This programme was a complement to, rather than a substitute for, the traditional command-and-control approach.

Experience with the programme has instilled confidence in it among the major participants. Air pollution regulators, who were once very opposed to transferable entitlements, have become a major source of support for the sulphur allowance programme and were instrumental in its design. Environmental groups have also begun to lend their support.

(b) *The existing programmes in the United States have lowered compliance costs while improving air quality.*

The programme has unquestionably and substantially reduced the costs of complying with the requirements of the Clean Air Act. Most estimates place the accumulated capital savings for all components of the programme at over $10 billion. This does not include the recurring savings in operating costs.[36]

Somewhere between 7,000 and 12,000 trading transactions have been completed. Each of these transactions was voluntary and for the participants represented an improvement over the traditional regulatory approach. Several of the transactions involved the introduction of innovative control technologies.

Though designed primarily to reduce the compliance costs of achieving predefined environmental goals, the emissions trading programme has also brought about an improvement in air quality. Facilitating compliance with the pollution control acts by making compliance cheaper and easier has been one avenue for improving air quality. Trading has increased the possible means for compliance and sources have responded. Other avenues by which emissions trading has improved air quality include: (1) providing a basis for more stringent standards, (2) encouraging banked emission reduction credits, and (3) developing trading rules that extract an "improvement premium".

In the negotiations over the sulphur allowance programme it became clear that industrial representatives were more willing to accept a larger reduction of sulphur oxides once it became clear that allowance trading was going to be possible. Since introducing trading lowers the cost of compliance (making it easier to reach any given target reduction), larger target reductions could be achieved at a lower financial cost than would have been possible with a pure command-and-control approach. Allowing trading increased the political acceptability of larger reductions.

Banking not only provides incentives to create credits for future use, it also offers an incentive for some credits to remain unused. While normal credits are used to justify emissions, the pollutant flows justified by banked credits are not being emitted. This reduction in actual emissions represents an improvement in air quality for as long as the credits remain banked.

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35 Strategic price behaviour is not the only potential source of market power problems. Firms could conceivably use entitlement markets to drive competitors out of business. See Misiolek and Elder (1989). For an analysis which concludes that this problem is relatively rare and can be dealt with on a case-by-case basis should it arise, see Tietenberg (1985).

36 For detailed evaluations see Dudek and Palmisano (1988), Hahn (1989), Hahn and Hester (1989a) and Tietenberg (1985) and (1990).

Finally, the emissions trading programme has opted to improve air quality by requiring trading ratios in excess of 1:1. For example, buyers must typically acquire 120 per cent of the entitlements they actually intend to use. If a facility wishes to use credits to justify a 10 ton reduction, they must actually purchase 12 tons. The extra two tons represent an improvement in air quality.[37]

(c) *Transferable entitlements seem to have worked particularly well for trades involving uniformly mixed pollutants and for trades of non-uniformly mixed pollutants involving contiguous discharge points.*

It is not surprising that most trades concluded have been internal (with the buyer and seller either forming part of the same corporation or sharing a common corporate parent) rather than external. Not only are the uncertainties associated with interfirm transfers avoided, but most internal trades involve contiguous facilities that are not required to supply dispersion model results. The fact that so many trades have taken place between contiguous discharge points serves as confirmation that substantial savings can be achieved even if the geographic boundaries of the trading area are quite restricted.

It is also not surprising that the majority of trades realized involve volatile organic compounds, which are uniformly mixed pollutants. Since dispersion modeling is not required for uniformly mixed pollutants even when the trading sources are somewhat distant from one another, trades involving these pollutants are cheaper to realize. In addition, trades involving uniformly mixed pollutants need not be concerned about local air quality deterioration since the location of the emissions is not a matter of policy consequence.

(d) *Transferable entitlements have encouraged technological progress in pollution control. Although, in general, the degree of progress has been modest, it has been more dramatic in areas where emission reductions have been sufficiently stringent to restrict the availability of emission reduction credits created by more traditional means.*[38]

Theory would lead us to expect more technological progress with emissions trading than with a command-and-control policy because it changes the incentives so drastically. Under a command-and-control approach technological changes discovered by the control authority typically lead to more stringent standards (and higher costs) for the sources. Therefore, sources have little incentive to innovate and a good deal of incentive to hide innovations from the control authority. With emissions trading, on the other hand, innovations allowing excess reductions create saleable emission reduction credits.

The evidence suggests that the expectations based on this theory have been borne out, but to a limited degree in the operating programme. The most prominent example of technological change has been the substitution of water-based solvents for solvents containing volatile organic compounds. Though somewhat more expensive, this substitution made economic sense once the programme was introduced.

The number of new innovations stimulated by the programme has been rather small. As long as cheaper ways of creating credits within existing processes are available, it would be unreasonable to expect large investments in new technologies with unproven reliabilities. On the other hand, as the degree of control rises and the supply of readily available credits dries up, the demand for new technologies can be expected to rise as well. This expectation seems to be borne out in those areas where unusually low air quality or stringent regulatory rules have served to limit the available credits.[39] This point is highly relevant to the control of greenhouse gases since control costs are ultimately expected to be very high.[40]

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37 Note that unlike the introduction of banking and encouragement of greater compliance, this source of improved air quality extracts a cost-effectiveness penalty. The use of trading ratios to produce better air quality leads to fewer trades and lower cost savings.

38 For more details see Tietenberg (1985) and Dudek and Palmisano (1988).

39 For the experience in California see Dudek and Palmisano (1988).

40 See, for example, Blitzer *et al.* (1991), Hogan (1990), Jorgenson and Wilcoxen (1991) and Manne and Richels (1990).

C. Conclusions

Key lessons

The experience with market-based programmes has demonstrated that they have had a positive role in environmental policy and can continue to have this in the future. The issue is no longer ***whether*** they have a role to play, but rather ***what kind*** of role they should play. The available experience with operating versions of these programmes allows us to draw some specific conclusions which facilitate defining the boundaries for the optimal use of market-based approaches.

(a) *Transferable entitlement systems offer the possibility of achieving greater environmental improvement at a lower cost than the conventional approach of allocating nontransferable quotas.*

Allowing reductions above the required amount to be transferable increases the opportunities for compliance. Enhanced opportunities for compliance in turn reduce the costs of compliance and lead to greater willingness to accept more stringent reduction goals. Transferable entitlements also encourage the development and installation of new and more environmentally benign technologies.

(b) *Full-blown entitlement markets are not necessary to achieve environmental and cost-effectiveness goals. Experience in the United States has shown that even hesitant initial steps towards a fully transferable entitlement system can provide the foundation for the eventual evolution of a rather sophisticated system engendering significant political support.*

Even a limited transferable entitlement market characterized by bilateral trades can provide a viable alternative to traditional regulatory approaches. Every trade realized reduces compliance costs. The experience of participants with limited trading lays the groundwork for the evolution of more sophisticated approaches which circumvent the pitfalls uncovered by the early experience. Supporting institutions (such as brokers and exchange markets) begin to evolve along with the entitlement system and help to make the system operate more smoothly and successfully. As the key participants gain familiarity with (and confidence in) the approach, its continued evolution is facilitated.

(c) *As greenhouse gases are appropriately treated as uniformly mixed, they fall within the category of pollutants for which transferable entitlement systems work best.*

For uniformly mixed pollutants only the amount emitted is a policy concern; the location of the emissions does not matter. The transferable entitlements system is particularly effective for this category of pollutants because trades can be on a one-for-one basis, no diffusion modeling is required (reducing transactions costs), and local "hot spots" are not a problem.

(d) *Compared to local or regional applications, the global nature of a transferable entitlement market in greenhouse gases offers the maximum potential for cost reduction and the minimum potential for problems such as the rise of market power.*

In general, the larger the number of potential participants in a transferable entitlement market the greater the number of possibilities for lowering the cost of compliance. Global markets offer the maximum opportunities for participation.

More participants not only open up more potential sources of emission reduction, they also diminish the likelihood of market power. Large numbers of buyers and sellers make the cartelization of any market difficult if not impossible.

(e) *As transferable entitlement systems allow the issue of who will pay for control to be separated from that of who will undertake control, they allow distributional and cost-effectiveness goals to be pursued simultaneously. They also facilitate technology transfer by providing a means for cost-sharing and risk-sharing.*

Regardless of the initial allocation of entitlements, the trading that would subsequently take place would provide the means for greenhouse gases to be controlled cost effectively. This is a particularly important feature when, as is the case with control of

the greenhouse gases contributing to global warming, concerns about fairness and affordability preclude simple solutions such as equal proportional reductions. Even very complex international allocations of the control responsibilities, which are sensitive to a host of individual country concerns, can be fully compatible with achieving the desired emission target at the lowest possible cost.

Cost-sharing and risk-sharing can be achieved even for very limited versions of transferable entitlement systems. In the United States now, for example, some manufacturers of sulphur oxide control equipment have indicated a willingness to install pollution control equipment free of charge, taking only the sulphur oxide allowances in return.[41] In this way the recipient utility incurs neither a financial burden nor a financial risk; the equipment supplier is willing to assume both by accepting the allowances as payment. It is not difficult to imagine equipment manufacturers striking a similar deal with developing countries should a transferable carbon dioxide entitlement system be implemented.

(f) *Implementing a free distribution of entitlements would allow global warming goals to be achieved with a lesser financial burden for polluters than either a traditional regulatory approach or an emissions charge approach which achieves comparable reductions.*

Traditional regulatory approaches are not cost effective; they impose extra control costs which can be eliminated, or at least reduced, by a transferable entitlement system. Those with high marginal control costs can secure entitlements from others with lower control costs. Entitlement buyers gain because they can fulfil their responsibilities at a lower cost than without trading. Sellers gain because they receive revenue that can be used not only to meet the costs of undertaking the greater-than-required reductions, but for other worthy projects as well.

While emissions charges can support cost-effective pollution control, they impose an extra financial burden. All uncontrolled emissions are subject to a fee and result in a flow of revenue to the government. With an emission fee set high enough to produce the desired reductions in greenhouse gas emissions, this revenue flow (and the financial burden associated with it) would be very large indeed. Under a free distribution entitlement system no fee would be automatically assessed on uncontrolled emissions.

(g) *If raising revenue becomes an important component in the coalition building strategy followed by negotiators, revenue could be raised while using a transferable entitlement system by levying a low annual fee on each entitlement. This revenue could be used for financing technology transfers or for other worthy purposes without jeopardizing the cost effectiveness of the system.*

Although an annual fee is not a necessary component of a transferable entitlement system, it can be added, if so desired. This combined system would leave the control of emissions to the quantity-based entitlements, while using the fee to raise revenue.

Coupling a low annual fee with a free distribution of entitlements provides an attractive alternative to both auctioned entitlements and an emissions charge. Owing to the political reluctance to establish rates as high as would be required to achieve the kinds of targets that are being discussed, emission charges have traditionally not been very effective in producing the desired level of emission reduction but they have been effective in raising revenue for environmental purposes. Conversely, while entitlements distributed free of charge have been effective in producing the desired level of control, they produce no revenue. The combined system provides complete assurance of sufficient emission reduction while raising revenue and encouraging even greater reductions.

Since uniform annual fees applied to the quotas do not affect the cost effectiveness of the system, the fee can be as low or as high as necessary to achieve the desired revenue result. While the fees do lower the entitlement price, they do not affect the incentive to trade.[42]

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41 I am indebted to Dan Dudek of the Environmental Defense Fund for pointing this out.

42 Although the entitlement price is lowered, the incentive to trade is preserved by the fact that a seller not only receives the price for the entitlement, but is also able to avoid paying the annual fee any longer on it.

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Chapter V

EQUITY CONSIDERATIONS OF TRADEABLE CARBON EMISSION ENTITLEMENTS

Adam Rose*

Summary

A system of tradeable entitlements is intended to achieve a CO_2 abatement target at the lowest global cost. A corollary of the underlying rationale of this policy instrument is that this goal can be achieved regardless of how the entitlements are distributed among nations. But the allocation does make a difference in two important respects. First, it may affect the number of countries that are willing to sign an agreement. Second, some allocations are more consistent than others with respect to international policy goals, such as accelerating the development of the third world.

Given the likelihood of great disparities in costs and benefits for nations as a result of most allocation schemes, many nations may not be satisfied with a principle that treats their own welfare as a derivative of a global goal. They are more likely to be attracted to an agreement by a principle that focuses on their absolute and relative well-being. Equity, or fairness, may serve as such a principle.

This chapter presents 10 international equity principles and transforms them into operational rules for allocating carbon entitlements. It also specifies reference bases by which these equity criteria can be measured. They include dynamic reference bases that take into account the features of CO_2 cumulative emissions and the relatively high opportunity cost of abatement, in terms of future growth for developing countries.

The findings indicate that alternative equity principles lead to widely divergent outcomes in terms of relative gains and losses. However, trading erodes these differences significantly. The analysis is intended to give policy-makers a clear indication of the economic outcomes of alternative entitlement allocations.

* Department of Mineral Economics, College of Earth and Mineral Sciences, The Pennsylvania State University.

Introduction

Any successful policy to deal with global warming must have several attractive features. Given the potentially immense sums that may have to be spent on abatement, it is important that the policy be cost effective. Given, too, the magnitude of the costs and the variation in both costs and benefits across countries, it would be desirable that the policy be equitable, or fair.[1]

Equity considerations are usually accorded a secondary role in most economic policy-making, but, in the case of global warming, there are reasons why they may be paramount. First, there is no supranational institution that can force a greenhouse gas (GHG) agreement; hence, volunteerism is of great importance. Secondly, appeals to economic efficiency will not be sufficient to rally countries together, given the wide disparities in their current welfare and the welfare changes implied by efficient policies.

Thus, over and above the usual role of equity in promoting fair policy outcomes, this criterion might serve as a unifying principle in forging a greenhouse warming agreement. A global problem requires a global solution and hence as many participants as possible. The public good character of GHG abatement means it is prone to "free rider" problems. At the moment, a few countries may be responsible for most of the emissions of CO_2 and other GHGs, but, as development proceeds, the number of critical countries will increase dramatically. Greater cooperation is likely to be forthcoming if the policy process and policy outcomes are perceived to be fair.

A tradeable permits, or entitlements, scheme for abatement has several attractive features, which are discussed elsewhere in this study (see also Tietenberg, 1985; Hahn and Hester, 1989). One of these is the separability of efficiency and equity considerations. Following Coase (1960), this means a tradeable entitlements scheme will be efficient no matter what their distribution. We are not faced therefore with the usual equity-efficiency trade-off. The trade-off is between various equity principles and the degree of comprehensiveness that they can inspire.[2] Some compromises may arise to bring more countries into the fold to share the cost burden. That is, some countries may shift to an equity principle other than their first choice in order to lower their own cost of abatement, even if the result is a less pleasing overall distribution of net welfare changes.

One significant problem arises with respect to equity, however. Unlike efficiency, there is no universal consensus on the best definition at either the international or interpersonal level. There are various levels at which international equity can be examined. Until recently, the topic was virtually ignored, even in the context of global climate change, which has been a subject of economic analysis for 20 years.[3] Most policy pronouncements include ambiguous or erroneous definitions of equity. Many also confuse the point of reference by which a policy is evaluated in relation to equity and the equity principle itself. A good example is the proposal that permits be allocated on the basis of population. Usually only brief discussions of the equity implications are offered, if at all (see, e.g., Epstein and Gupta, 1991, who acknowledge the need for a more definitive analysis). As we will show below, entitlement allocation on a per capita basis is consistent with several equity criteria.

Thus, we will begin with a detailed analysis of 10 equity principles, including their transformation into operational rules for global warming policy in general and tradeable entitlements in particular. We will then proceed to discuss alternative reference bases and match them with equity principles. We will also show how these bases can be

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1 Equity in this chapter refers to the fairness of the distribution of costs and benefits across countries, i.e. "international equity". This differs from dynamic, or intergenerational, equity, which is another major consideration in global warming policy. It is the author's contention that these two types of equity can be analysed separately. Some aspects of the dynamics of equity will be analysed in sections D and E below.

2 Efficiency, in the form of cost effectiveness, may be affected if countries with the very lowest control costs do not participate.

3 Recent work explicitly dealing with equity includes: d'Arge (1989), Chapman and Drennen (1990), Rose (1990), Bergesen (1991), Burtraw and Toman (1991), Solomon and Ahuja (1991) and Young (1991). There are also major discussions of equity criteria in Grubb and Sebenius (1991) and Schelling (1991).

measured with currently available data, as well as how ideal versions of them can be defined. Finally, we will explore the implications of the various criteria in terms of who gains and who loses. Equity criteria pertain not only to the initial allocation of entitlements but also to the final incidence of costs and benefits, i.e. the results after trading takes place and any accompanying exchanges or additional transfers are made (see, e.g., Barrett, 1991; and Whalley and Wigle, 1991).

It is hoped that clarification of the matter of equity in global warming agreements will facilitate cooperation among nations. It is also hoped that it will ensure the fair distribution of the policy burden between industrialized countries and developing countries.

A. Equity, economic development and global warming policy

The purpose of economic development is to improve the capabilities of economies to provide a higher standard of living for their populations. The implicit or explicit intent is also to narrow the gap between rich and poor nations.

The process of economic development has proceeded rather slowly on its own for many countries, and, in response, a tradition has been established for relatively wealthy, usually industrialized, nations to offer development assistance in such forms as cash grants, loans or loan guarantees, technical assistance, etc. The motivation for this "foreign aid" is often altruism for the purpose of promoting several of the equity ideals to be discussed below. In other cases, the intent is the promotion of self-interest through the creation of new markets or the promotion of ideology. While the transfers from industrialized to developing countries total tens of billions of dollars annually, they typically represent less than 1.0 per cent of the GNP of any of the donors.

For several reasons it is important that environmental policies should not counteract the development process. This could happen if entitlements were allocated to developing countries at a level much lower than emissions of greenhouse gases. A high abatement cost burden would stifle the strong forward momentum in some developing countries and make it even more difficult to maintain large segments of the population above subsistence levels in others. Diversion of development assistance to promote environmental goals would also be problematic for economic growth. The Coase Theorem implies that the distribution of property rights is irrelevant, but it should be kept in mind that this pertains only to efficiency. For the sake of promoting future economic development the allocation pattern does matter. Tradeable entitlements thus have the relative advantage of making allocations explicit so that their consistency with other policies is readily apparent. The market for entitlements will also involve resource flows, whose directions are easy to predict, and which can also complement development policies. Moreover, any undesirable distributional consequences can be offset by side payments, or transfers, without adversely affecting efficiency.

Estimates of the cost of CO_2 abatement should also incorporate development considerations. The opportunity cost of resources used for abatement should include (the present value of) future output that could otherwise have been attained. For countries anticipating a high rate of economic growth, namely developing countries, this means a dollar spent on abatement will be relatively more burdensome than for others. This may manifest itself in other ways. The environmental premium on the burning of fossil fuels is likely to devalue extensive resources, such as Chinese coal and Nigerian oil (see sections D and E below).

It is also important to emphasize that there is a growing consensus that economic development and environmental quality are intertwined. Their mutuality is best conveyed by the theme of ***sustainable development***, defined as the improvement of the material quality of life without drawing down assets, primarily material ones, that would diminish prospects for future generations (see, e.g., the Brundtland Report, 1987; Pearce *et al.*, 1989; and Kinuthia and Nyangena, 1991). Thus, the investment by developing countries in environmental protection is an investment in their future economic development. But in

those countries that would suffer little damage from global warming this investment is likely to yield a lower return than if applied less to global environmental protection, or possibly directly to economic development.

Equity is also a theme of sustainable development (see, e.g., the Brundtland Report, 1987). In this case the emphasis is on income distribution ***within*** a country. In general, there is always a concern that development should filter down to those who need it most. A related implication of sustainable development is that the entire population should participate in its rewards, a situation that is considered more likely if everyone participates in the associated decision processes and work efforts.

A related concern is the fact that developing countries and especially the poorer people within them are the most vulnerable to the catastrophes, such as flooding and famine, that have been predicted to materialize as a result of climate change. For example, a disproportionate number of the economically disadvantaged are inhabitants of flood plains and low-lying areas in countries like Bangladesh, India, China and Egypt.

Equity often refers to the fairness of the decision in process and the operation of the policy, as well as to its outcome (see, e.g., Kasperson and Dow, 1991). Concerns have been raised about the relative power of industrialized nations to force an unwelcome agreement upon developing countries. While many see the freedom of choice in entering into transactions as one of the strengths of a marketable entitlements scheme, some see it as simply extending the boundaries of the realm of "unequal exchange". Others have noted that tradeable entitlements schemes have been worked out in terms of what is considered important in developed countries, but do not take into account the institutional structure of developing countries. They also fear the subtle outcomes of an entitlements scheme that would have adverse effects, such as the possibility that higher production (plus abatement) costs in industrialized nations might become a pretext for establishing discriminatory trade policies. At the same time, the improvement of the terms of trade for developing countries is acknowledged (Kinuthia and Nyangena, 1991).

Finally, it should be noted that not all efforts to promote equity in the context of global warming policy will necessarily increase one nation's welfare at the expense of another's. Often initiatives can involve the satisfaction of mutual interests. The transfer of more efficient energy utilization technologies from industrialized nations to the third world obviously benefits the latter, and has the effect of lowering the marginal cost curve of abatement, and hence the world price of entitlements, to the benefit of the former. It may also open new markets for the technology and provide valuable operational experience, which will help in its deployment in all countries.

B. International equity criteria

Equity represents a normative evaluation, or value judgement, of the social desirability of economic and non-economic disbursements, both positive and negative. The concept has been a major focus of philosophers since ancient times and has been the implied or explicit concern of monarchs and politicians for at least as long. The vast majority of attention has been devoted to the distribution of well-being among individuals, but when gains and losses transcend political boundaries the unit of analysis enlarges accordingly. Below, we offer several equity principles applicable to global warming policy. In most cases, we begin with the more typical interpersonal context and then show how the concept can be extended to the international arena. The equity principles, a general operational rule emanating from each, and a rule applicable to the allocation of tradeable entitlements for CO_2 emissions, are summarized in table 1.[4]

4 Many distribution formulas have been offered to accompany proposals for tradeable entitlements and other policy instruments. Most of them have been aimed at the matter of equity, though some appear to be intended primarily to deal with aspects of monitoring and enforcement.

Table 1

ALTERNATIVE EQUITY CRITERIA FOR GLOBAL WARMING POLICY

Criterion	*General operational rule*	*Operational rule for CO_2 entitlements*
Horizontal	Equalize net welfare change across nations (net cost of abatement as proportion of GDP equal for each nation) [a]	Allocate entitlements to equalize net welfare change (net cost of abatement as proportion of GDP equal for each nation) [a]
Vertical	Progressively share net welfare change (net cost proportions inversely correlated with per capita GDP) [a]	Progressively distribute entitlements (net cost proportions inversely correlated with per capita GDP) [a]
Ability to Pay	Equalize abatement costs across nations (gross cost of abatement as proportion of GDP equal for each nation) [b]	Allocate entitlements to equalize abatement costs (gross cost of abatement as proportion of GDP equal for each nation) [b]
Sovereignty	Cut back emissions proportionally across all nations	Allocate entitlements in proportion to emissions
Egalitarian	Cut back emissions in proportion to population	Allocate entitlements in proportion to population
Market Justice	Make greater use of markets	Auction entitlements to highest bidder
Consensus	Seek a political solution promoting stability	Distribute entitlements so that (power weighted) majority of nations are satisfied
Compensation	Compensate net losing nations	Distribute entitlements so that no nation suffers a net loss of welfare
Rawls' Maximin	Maximize the net benefits to the poorest nations	Distribute large proportion of entitlements to poorest nations
Environmental	Cut back emissions to maximize environmental values	Limit entitlements associated with vulnerable ecosystems (e.g. forests)

Source: Table prepared by the author.
a Net cost equal to the sum of mitigation benefits - abatement costs + entitlement sales revenues - entitlement purchase costs.
b Gross cost refers to abatement cost only.

Before proceeding to our analysis, we point out a confusion in the literature arising from the failure to distinguish between fundamental equity criteria and what we will term "reference bases." The former refer to general concepts of distributive justice or fairness and the latter to specific measures or indices to which the equity principles can be applied according to the policy issue under examination. It is not surprising that many analysts emphasize the latter. Reference bases are more concrete and less controversial than ethical principles.[5] On the other hand, their equity implications are often am-

[5] Reference bases have the desirable properties of focal points, a term Schelling (1960) coined to represent a key, facilitating feature of negotiation processes. Toman and Burtraw (1991) suggest that "negotiators will seek out rules of thumb...," but also note that, because of strategic considerations, it is unlikely that "...simple rules of thumb alone can successfully guide the negotiation process". They go on to state: "Thus strategic and procedural aspects of negotiation can be viewed as essential to the evolution of a commonly shared standard of equity that must accompany an international agreement" (Toman and Burtraw, p. 12). Morrisette and Plantinga (1991; p. 6) have likewise stated: "Success, however, will depend on how the different stakes of nations can be dealt with in the negotiation process in an equitable manner". We will give primacy to equity principles in the pres-

biguous or not really what is claimed. Examples (to be discussed in detail below) are population, which is consistent with several conflicting equity criteria (e.g. egalitarian, sovereignty, consensus), and land area, which is at best only weakly related to some criteria. In addition, there are dynamic versions of these reference bases, relating to past (cumulative) and future (development-related) emissions, the damage these cause, and the cost of mitigating them.

There is also the question of the object of equity analysis, or what exactly is being distributed. The most straightforward consideration is the cost of mitigation. From a more comprehensive perspective, however, we would consider the net welfare change, or net cost. The net cost is equal to the sum of mitigation benefits and entitlement sales revenues minus abatement costs and minus entitlement purchase costs.[6] There is a temptation to simplify the analysis and merely confine it to abatement costs, but for the purpose of achieving an agreement one cannot ignore the magnitude and variations across nations of benefits from avoiding global warming damage. Even if the scientific community feels these benefits can never be accurately measured, nations are likely to have strong perceptions of the magnitude of the benefits, a factor that will influence their negotiating positions. Thus, while we can simplify the analysis of tradeable entitlements from the standpoint of efficiency by resorting to cost-effectiveness analysis (i.e. simply assuming a given CO_2 reduction level and examining whether it can be attained at least cost), we do not necessarily have this luxury from the standpoint of equity.

Our analysis will proceed from the most fundamental level in order to provide a solid foundation for policy proposals. Thus, we will first examine individual equity criteria and then discuss their implementation through various reference bases.

1. ***Horizontal equity*** calls for all persons in the same group to be treated equally, the grouping being as narrow as an occupational category or as broad as citizenship. It emanates from basic precepts of human equality and has its policy basis in national constitutions and subsequent amendments (e.g. the United States Bill of Rights). As such, on an individual basis, horizontal equity probably has very solid policy underpinnings. In one of its most recent applications it has served as the foundation for the promotion of equal opportunity, though it can just as readily be applied to the equality of outcomes.

Extended to the international arena, this criterion would serve as a basis for the equal voting power of all member nations in world bodies, such as the United Nations General Assembly. Further extended to the international level, it would require the equal division of resource discoveries, the spoils of war or policy burdens, regardless of the relative wealth of the countries involved.

For the issue of global warming in general, horizontal equity requires the equalization of the abatement cost burdens across nations. This means that the net cost of abatement as a proportion of GDP should be set for all nations. In the case of tradeable CO_2 entitlements or quotas, this entails allocating entitlements in such a manner as to have percentage changes in net welfare equalized across nations.

2. ***Vertical equity*** calls for improvement of the position of the individuals or groups of lower station relative to those at the top of the scale. Rather than calling for across-the-board treatment, vertical equity expresses greater concern for the disadvantaged. On the philosophical plane, it has some of the deepest roots of any of the alternative concepts. Aristotle, in the spirit of his Philosophy of the Golden Mean, is said to have enunciated the precept that no man in the kingdom should have wealth in excess of three times the level of any other. This illustrates two important aspects of vertical equity: equity and equality are not necessarily synonymous and it is difficult to make a vertical equity rule seem non-arbitrary.

There is no explicit legal basis for vertical equity in most countries, but it manifests itself in interpersonal cases, such as pro-

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entation to follow. If global warming were an uncomplex issue that could be settled in a short time, we would endorse the more pragmatic "rule of thumb" approach. But as the issue is complex, and negotiations are likely to take years, and to go through several stages, it is imperative for them to have a solid foundation. It is the author's contention that countries are more likely to rally around higher ideals under such circumstances and that these equity principles need to be thoroughly articulated and their full implications understood before a sound agreement can be reached.

6 There are several ways to conceive of abatement costs. As will be discussed below, we prefer general equilibrium effects (interactive impacts on the entire economy), as opposed to partial equilibrium measures (direct costs). In addition, we confine our attention to incremental costs, those over and above the expenditures already being made explicitly to abate CO_2 or that result in abatement in the course of meeting another objective. Note that benefits should include consumer surplus as well as general equilibrium effects.

gressive income taxation. The potential for tensions between the "haves" and "have nots" to promote political instability within national boundaries extends across these boundaries as well. On the other hand, adherence to the vertical equity principle allows for a collective manifestation of altruism. Foreign aid by industrialized nations is a prime example of vertical equity policy often motivated by altruism, as are those treaties with terms favourable to the relatively less well-off nation.

The application of this criterion to global warming would involve some "progressive" sharing of the net cost burden, as in inversely correlating it with per capita GDP. For a tradeable entitlements scheme, this could translate into allocating a higher proportion of the entitlements to developing countries. Moreover, the extent of the progressivity must be sufficient to offset any regressive tendencies of the trading process.

3. ***Ability to pay*** refers to paying according to one's means. It is one of the traditional principles of public finance in reference to the imposition of taxes. Any fixed tax rate applied to a base corresponding to economic well-being (e.g. income or property) is an example. As such it most closely corresponds to vertical equity, though the latter does not require proportionality. There may be a temptation to liken it to horizontal equity if the focus is on the tax rate.[7]

In the context of global warming, the principle would apply only to the cost burden, as opposed to the benefit and cost (net welfare) calculus.[8] To contrast the principle with vertical equity as much as possible, we will not even include the cost of purchasing entitlements.[9] The operational rule would then call for allocating entitlements so that abatement cost proportions were equalized. This would mean that no nation could receive entitlements in excess of its emissions, i.e. all nations would incur at least some abatement costs.

4. ***Sovereignty*** implies that each entity is guaranteed at least a minimum of basic rights, resources or opportunities. This concept is actually more readily conceived in terms of national entities, though it is similarly applicable to individuals (e.g. some minimal sustenance is accorded to citizens of many nations through welfare programmes). In our context, it represents the basic rights of national entities, often focused on territorial integrity. Transboundary pollution is considered as an "invasion" in this context. Numerous defence pacts and other international agreements (including article 21 of the United Nations Declaration on the Human Environment) are based on this principle and it would seem to be applicable to the case of global warming.

Of course, in its strictest form, sovereignty is untenable since it would prohibit pollution. A relaxed version has the implication that no nation or person has any more or less right to inflict or suffer damage than any other. The "polluter pays" principle, adopted by the OECD in the context of transboundary pollution, embodies some elements of this criterion. This criterion would be implemented by making the cutbacks proportional across nations. In the special case of tradeable entitlements, it would mean allocating these in proportion to emissions.

5. An ***Egalitarian*** ethic would treat every human being equally, no matter where he/she resides or his/her socioeconomic status. Probably even more fundamentally than horizontal equity, it emanates from basic precepts of human equality as embodied in the constitutions of many countries. One version considers everyone to have a natural right of access to the global commons, though its use to sustain life and its use as a dumping ground come into conflict once its assimilative capacity is breached.

Interestingly, this is a purely individualistic criterion that transcends national entities, so it applies to the international setting unchanged. Its sole requirement would appear to be that emission entitlements should be allocated on a population basis. Actually, this may be superficial since it focuses only on the right to pollute. On the benefits side (the right to be free from pollution damage), this criterion is consistent

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7 This is how progressive income tax avoids coming into conflict with equality strictures in the United States Constitution. The same marginal rate is applied to a given unit of income (bracket) for everyone who earns it. Higher income taxpayers just have more units to which higher marginal rates are applied, thus causing a differential in average rates.

8 A counterpart of ability to pay is the "benefits" principle of public finance, which calls for the imposition of the tax in conformity with the benefits gained from expenditure of tax revenues. Given the difficulty in measuring the benefits of global warming policy, we do not consider this an operational principle. Some aspects of a benefits criterion might, however, be combined with more obvious examples of benefits (e.g. Canada and the Maldives).

9 The flatter the marginal cost of abatement the less this matters.

with all others, since CO_2 control is a global "public good" and every person has equal access to it.

6. ***Market justice*** refers to the contention that the free market is a "fair" means of allocation and distribution and that the outcome yields "just desserts." The main emphasis, however, is on the even-handedness of the process, which does not require an even distribution of outputs or incomes. Lane (1986) uses the term "market justice" in contrast to "political justice", the latter focusing on the fairness of outcomes and thus ironically coming closest to the several more conventional definitions of equity. He contends that most people favour market justice, one of the major reasons being that the market does not play favourites nor is it more subject to abuse of power than government. The market is also seen to offer efficiency and growth. Thus, interfering with the market through redistribution has only limited public support in countries such as the United States. At the same time, this view ignores the likelihood of market failure in the real world. Such failure often provides a rationale for government intervention or at least steps to improve or monitor markets.

In the international domain, this principle would suggest relying on more market-oriented policy instruments, such as tradeable entitlements for CO_2. However, the criticisms of market outcomes are significant. Welfare economics endorses a perfectly competitive economy as promoting efficiency, but few economists would suggest that the market is not blind to equity. Moreover, non-competitive markets, prominent in aspects related to global warming (e.g. world oil), lead to a concentration of income and are not efficient either.

In the case of global warming this criterion suggests making greater use of markets. Coase (1960) and others have emphasized that pollution, and externalities in general, arise from an absence of clearly delineated property rights. A tradeable entitlements scheme remedies this problem in an ironic way by defining and assigning what may be viewed as rights to pollute. The fact that these rights are tradeable means that the resource involved, the environment, is utilized in the most efficient manner, or that pollution control takes place at the least possible cost. Interestingly, it is usually concluded that this result takes place no matter who receives the rights.[10] Thus, equity is often ignored. In the context of market justice, the most consistent approach would be to let the market decide on the assignment, i.e. to auction off entitlements to the highest bidder.

7. ***Consensus equity*** arises from the implications that the outcome of the political or diplomatic process is just. Compared with the previous ethical criteria, which require an analytical examination and evaluation of the distribution of policy consequences, consensus equity stems from the conviction that a policy decision is fair if parties agree to it (see, e.g., Lindblom, 1977). The concern here again is not with basic considerations of evenness (horizontally, vertically, etc.), but simply with the fairness of the process. In many ways the situation is analogous to market justice, in this case for the political arena, in what are considered fair contexts, e.g. democracy. However, given the influence of economic and military power in international politics, the actualization of a "fair" outcome is suspect. This "political failure" situation is analogous to market failure, but in this case emanates from a concentration of political (rather than market) power.

In the case of tradeable entitlements, consensus equity means they would be assigned broadly so as to satisfy (to a reasonable extent) a large array of nations, but would definitely include powerful, or otherwise influential, ones. This consensus may be facilitated by transfers or other concessions.

8. ***Compensation***. Pareto Optimality, or its policy extension, the Pareto rule, allows a policy to be implemented only if it avoids making even one of the affected parties worse off. To free policy-makers from the straitjacket of a rule that would result in real world policy paralysis, since policies can rarely be implemented without imposing net costs on at least one group, various compensation schemes have been devised. They call for the adoption of a policy as long as the winners can compensate the losers to the extent that both parties are made better off (essentially the positive net benefit criterion of cost-benefit analysis).[11] Early proponents of this criterion suggested that compensation need not actually be paid, but only that a "po-

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10 There is some criticism of the equity neutrality of the property rights solution. For example, an individual's bid, reflecting his or her willingness to pay, is affected by an income constraint.

11 There are some conceptual difficulties in the evaluation of the optimal level of compensation. See also Barrett (1991) and elsewhere in this study for a discussion of the relative merits of compensation and its likely magnitude.

tential" Pareto improvement is necessary to justify the policy; others suggested compensation could be used to even out the distribution of gains. Thus, depending on the attitude towards compensation and its exact level, the compensation test can be viewed as having no equity implications of its own, implications similar to those of vertical and horizontal equity, or its own implication (positive net gains for everyone). As regards global warming, the latter may not be possible without major income transfers, although some modified version could be confined to the mitigation of investment costs. The "polluter pays" principle might also be operative here in terms of compensation for damages.[12] In the context of this study, such compensation could be actualized through the allocation of the entitlements themselves and the subsequent transfers accompanying their sale.

9. ***Rawls' Maximin.*** Rawls (1971) has developed the basis of a social order focusing on "principles that govern the assignment of rights and duties and regulate the distribution of social and economic advantages". Rawls' principles are an extension of the contractarian branch of political philosophy in which "rules of the game" are established in a cooperative spirit. His basic concept of justice as fairness does not mean dictating the final outcome but rather applies to an initial rule-making situation in which no individual has or foresees an advantage over others, and thus has no incentive to bias the rules. Rawls believes each decision-maker will "justly" seek to establish safeguards against maldistribution brought about by chance. He offers two basic principles of justice, which can be summarized as equal right to liberty and the tolerance of inequalities only when they are to everyone's advantage. The second of these principles pertains to vertical equity, improvements of which are to be guided by Rawls' Maximin principle: the welfare of the worst-off individual is to be maximized before all others.

Although Rawls' work is based on a very idealized world, it is considered by many analysts to be the major contribution to the field in recent years. The Rawlsian concept of equity is therefore an excellent candidate for adaptation to international analysis. This means analysing the "contract" among nations in a "constitutional" setting. Operationally, it requires that special consideration be given to the poorest group of nations.[13] In our context, it means giving them a relatively very large share of entitlements.

10. An ***Environmental*** ethic also deserves to be mentioned. It arises from a diverse array of moral and religious principles and is the rallying cry of a powerful special interest group that transcends national boundaries. Expressed very generally, it gives primacy to the ecosystem as a whole or to certain environmental media considered to be the most vulnerable. In one version it would pertain to loss of unique sites, decrease in biological diversity (species extinction), and other irreversibilities. In a broader context, it would accord "rights" to the ecosystem to be free from attack, whether irreversible damage takes place or not. It implies, in fact, that there is a primacy about environmental resources and that they cannot be traded off against other objectives.[14] In the international arena, the extension of this criterion is complicated by the fact that ecosystems do not conform to political boundaries. In the context of global warming, this principle would dictate that entitlements must not be allocated to fragile ecosystems, such as forests.

Note again that we are focusing on equity criteria, but are not suggesting that other considerations are not important. We have avoided the usual discussions of equity-efficiency trade-offs, because they detract from our main theme. It should also be noted that there are considerable conflicts among our several equity principles themselves. Although references to equity are typically vague in most contexts, it is extremely important to define clearly which variant of the concept is being proposed in a global warming policy.[15]

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12 Baumol and Oates (1988) have noted, however, that the optimal response to an externality should not involve both taxing the polluter and compensating those damaged by the pollution.

13 At the same time, some analysts suggest implicitly that the rule is non-operative in a sense in today's international context, i.e. there are nations so disadvantaged (e.g. Bangladesh) that even massive aid cannot redeem them.

14 Proponents of this principle even resent references to the medical value of biodiversity or the recreational value of wilderness sites. Hence, they also defy being evaluated in terms of a common denominator, especially money.

15 Our equity criteria are somewhat ethnocentric, i.e. have a Western bias. Criteria based on precepts of Middle Eastern and Eastern religions should also be considered, given the global scale of the issue (see, e.g., d'Arge, 1989). Moreover, we have not considered all possible equity criteria (see, e.g., Baumol, 1986).

C. Static reference bases

We will now examine alternative reference bases to which equity criteria can be applied. These bases are essentially indices against which to gauge the equity implications of policy designs. We will distinguish between operational bases, those that can be utilized with data currently at hand, and ideal measures, those that require further conceptual refinement and/or data gathering in order to reflect the intent of underlying equity principles more accurately.

We will also distinguish between static measures, which pertain to a given point in time (including a future target date), and dynamic measures, which refer to a series of past or future levels of some of the measures. Reference bases, their applicability and their measurement are summarized in table 2. Data on several of the reference bases for a cross-section of eight representative nations or groupings are presented in appendix table A.

Two points are emphasized. Some equity criteria can have more than one reference base. Moreover, several reference bases are consistent with more than one criterion. This raises a concern about the ambiguity of many previous policy proposals, a concern our categorization hopes to clarify. At the same time, the lack of unique correspondence between criteria and measures may actually be a policy-making plus in that it allows for more flexibility and the possibility of satisfying more countries.

1. ***Economic Welfare***, or well-being, is one of the most prevalently used indices. It is comprehensive, encompassing both costs and benefits (including consumer's and producer's surplus). In the case of the criterion of overall economic efficiency (Pareto Optimality), it is maximized. In the case of efficiency without optimality or cost effectiveness, the implication is that it is at least increased if not maximized. Equity criteria are primarily concerned with its distribution. As noted in table 2, this base is applicable to half of our criteria. Exceptions are those where individual, national, or natural identities prevail (egalitarian, sovereignty, environmental) or where the process rather than the outcome is dominant (market justice and consensus). It should also be noted that its mathematical relationship with equity criteria varies. For vertical equity, there is an inverse relationship and for horizontal equity a proportional one.

The operational measure of economic welfare is per capita GDP. The ideal measure would encompass non-marketed goods and services (e.g. food grown for own use and environmental amenities) and would adjust for purchasing power parity. Refinements of this type are usually thought to narrow slightly the disparities between rich and poor nations.[16]

2. ***Population*** is often mentioned as a basis for allocating emission quotas or entitlements without much discussion of underlying equity considerations (see, e.g., Epstein and Gupta, 1991). Strictly speaking, this base is only consistent with the egalitarian criterion. To the extent that countries with large populations might wield more influence in negotiations, it is tied to the consensus criterion. Interestingly, the population index is often suggested as a way to help developing nations in the spirit of vertical equity. This outcome usually holds, but to a great extent by accident. There are situations, such as deforestation and methane from animals or rice paddies, where this reference base could work against these nations.

Grubb and Sebenius (1991) and others have noted a serious problem with the population reference base in that it provides an incentive to population growth, itself a major contributing factor to the global warming problem. Many have therefore suggested utilizing some population subset, such as adults, or a population baseline.

3. ***Land Area*** has sometimes been suggested as a reference base. Explicitly, it corresponds rather poorly to the various equity criteria. To the extent that land area

16 We also note the distinction between the economic welfare change for each country as the result of a given global warming policy and the use of economic welfare as a reference base in terms of the various versions of "relative deservingness" of each country with respect to the policy. In the latter case, it is measured on a per capita basis, while in the former it may be per capita or a proportion of GDP (see again table 1).

Table 2

STATIC REFERENCE BASES FOR CO_2 TRADEABLE ENTITLEMENTS

Reference base	*Applicability to equity criteria* [a]	*Operational measure*	*Ideal measure*
Economic welfare	Horizontal, Vertical, Ability, Compensation, Maximin	Per capita gross domestic product (GDP)	Per capita augmented GDP [b] (adjusted for purchasing power parity)
Population	Egalitarian (Consensus)	Population	Population (adjusted to discourage growth)
Land area	(Horizontal, Vertical, Environmental)	Square miles	Square miles (adjusted for travel costs)
Energy use	(Vertical, Environmental)	Btus (adjusted for carbon equivalence)	Btus (adjusted for carbon equivalence and fuel efficiency)
Energy reserves	(Horizontal, Vertical, Compensation)	Btus (adjusted for carbon equivalence)	Btus (adjusted for carbon equivalence and fuel efficiency)
CO_2 emissions	Sovereignty, Environmental (Horizontal, Vertical)	Emissions (adjusted for carbon equivalence)	Emissions (adjusted for carbon equivalence and fuel efficiency)

Source: Table prepared by the author.
a Parentheses indicate applicability is weak.
b Refers to GDP enhanced by non-market goods and services, primarily environmental.

might be positively correlated with economic development or the value of the environment, it may implicitly be related to horizontal, vertical or environmental versions of equity. Some have argued that the large land areas of the United States and other big countries are responsible for their high per capita fuel consumption as needed for transportation. Thus, land area might be used as a proxy to adjust bases such as energy use or emissions for "necessity."

4. ***Energy Use*** is often proposed as a reference base in place of emissions because it is easier to measure. It would appear to be only loosely related to various criteria, as in its positive, but not perfect, correlation with per capita GDP for use in inverse relation to vertical equity. Of course, energy use should be adjusted for carbon equivalence in relation to radiative forcing when policy is aimed at more than one type of GHG, lest this measure turn into a disincentive for shifting to non-fossil fuels. An even better version would contain another adjustment for fuel efficiency in order to promote dynamic efficiency (see, e.g., the proposal by Solomon and Ahuja, 1991) or various concepts of equity that distinguish between "necessary" and "unnecessary" consumption (often also referring to luxury goods).

5. ***Energy Reserves*** are not often suggested as a reference base. However, they may prove useful in two ways. First, they may serve as a major indicator of the wealth or welfare of a country. Secondly, they will prove useful in the discussion of dynamics below. The use of fossil fuels, most notably coal, will be discouraged by global warming policies. The forgone use of these resources will represent an opportunity cost to be considered in measuring welfare changes.

6. ***Carbon Emissions*** are another popular reference base, primarily because they are the direct stimulus to global warming. This is an appropriate counterpart to the sovereignty and environmental criteria when adjusted for carbon equivalence. As in the case of energy use, it is also pertinent to vertical equity to the extent that emissions are correlated with per capita GDP. To the author's knowledge, no analysts utilizing this base have linked it properly to an equity criterion (see, e.g., Manne and Richels, 1990).

D. Dynamic reference bases

1. *Past emissions*

The fact that GHGs are stock pollutants has important implications for the intergenerational allocation of resources forward in time, in terms of the usual issues relating to discounting (see, e.g., Nordhaus, 1989, and d'Arge, 1989). Going backward in time, in the sense of cumulative emissions, also has important implications for the specification of abatement requirements. In terms of efficiency, policy instruments should be applied only to current and future emissions, since built-up GHGs are analogous to sunk costs. From an equity standpoint, however, the stock nature of GHGs does matter. Industrialized nations have developed by abusing the global commons with little or no penalty. Ignoring the past build-up and simply basing reduction requirements on subsequent emissions would be equivalent to penalizing developing countries for their progress, when no such sanction was imposed on industrialized countries. Since the efficiency and equity aspects of tradeable entitlements are generally separable, we can address the latter without wasting resources.

Most of the equity criteria discussed in the previous section can be reinterpreted in terms of cumulative emissions. One way of incorporating this feature into equity analysis is to think of it as affecting a country's GHG "rights" or "responsibilities" where these are relevant. The consideration of rights arises in the context of sovereignty and the egalitarian ethic. Responsibility is not explicitly related to any of the criteria except sovereignty and the environmental ethic, and possibly rather weakly to consensus. Otherwise, it is simply compatible with all other criteria except market justice and one rigid form of egalitarianism.[17]

In addition, there are some equity criteria that are only relevant in the context of historical emissions and very explicitly so. A good example is Young's (1991) "status quo" or "adverse possession" criterion, which stipulates that the current rate of GHG emissions constitutes a "right" legitimized by usage and custom.

There are two straightforward ways of operationalizing past actions as a reference base. One is to consider cumulative CO_2 emissions minus an adjustment for absorption and decay over time. Another is to use cumulative emissions minus any absorption at time of release only. The latter would in effect be a measure of any instantaneous damage. This might not have been significant until recently, if at all, but is likely to be an increasingly important consideration when policy is being discussed in future years.

How would the other reference bases indicated in table 2 be affected? In most views they would not be. For example, policy-makers are likely to evaluate the vertical or horizontal equity of abatement, even if the level is related to cumulative emissions, in terms of ***current*** economic welfare (per capita GDP), ***current*** energy reserves, etc. There is the option of adjusting the various operational measures, other than emissions, to past levels, but there would seem to be little justification to do so. Finally, two reference bases are in effect applicable in nearly all cases - implicitly carbon emissions (past) are combined with per capita GDP, population, land area, etc.

The effect of including the cumulative emissions consideration in an adjustment of the reference base against which to measure equity is to alter abatement requirements or entitlement allocations accordingly. This would affect the cost side of the ledger. Certain climate engineering alternatives may in future allow for differential adjustments on the benefits side. It may be surprising to some, however, that the cumulative emissions reference base would not change the distribution of the CO_2 cost burden dramatically. Smith *et al.* (1991) estimate the split between industrialized and developing nations as 60:40 on a current basis and 70:30 on a cumulative one.

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17 The latter has been proposed by Fujii (1990) in terms of an equal emissions quota for each person regardless of his/her location or ***generation***.

2. *Future considerations*

The stock nature of GHGs, as well as the potential for them to be emitted at significantly higher rates as population grows and economic development spreads, justify special concern over future emissions. We will discuss these emissions in terms of both the simple case of current emissions at some future time and the dynamic case of trade-offs over a time horizon.

In the former case, the focus is on the fact that the contribution of developing countries to CO_2 emissions is likely to rise from 30-40 per cent of the world total, as it now is, to 60+ per cent in perhaps the next 30-40 years. The pressure will then mount to raise emission limits or reduce emission entitlements (or at least the surplus entitlements) for these countries. While there has been strong emphasis on the low cost of achieving emission reductions in the third world, especially if technology transfer takes place, there is also the prospect of implementing costly policies. One example is a policy to discourage coal use or to institute an outright ban. Under these circumstances, it may be legitimate to include the opportunity cost of devalued resources.[18] In countries like China, these costs could be huge. Their inclusion in the net welfare calculus would put such countries in a position to receive extra entitlements under criteria like vertical equity and Rawls' Maximin principle.

In the dynamic case, it must be emphasized that currently undertaking CO_2 abatement diverts resources from investment needed to stimulate economic development. While this abatement reaps future benefits, it also imposes costs on current and future generations in terms of both stock and flow measures of well-being. The opportunity cost therefore extends beyond the partial equilibrium aspects associated with fossil fuel reserves, and includes the general equilibrium lost surplus measures from forgone economic growth and development. The result is problematic in two regards. First, these nations are especially needy and, according to some specifications of welfare functions and views of equity, suffer more from a comparable decrease in the rate of economic growth than industrialized nations. Secondly, it breeds resentment in the third world, especially in the face of sizeable cumulative emissions by industrialized nations (see, e.g., Agarwal and Narain, 1991).[19] This situation is likely to have some significance for the utilization of criteria like consensus equity.

As noted in section A, however, we also need to consider the future benefits of avoiding the damage that could potentially stem from climate change. There is an additional opportunity cost to consider if environmental control or enhancement options, other than those resulting from a tradeable entitlement scheme, would have yielded a higher return.

Future emissions also have some dimensions of rights and responsibilities as discussed in the context of historical emissions, though typically to a lesser extent. The most obvious is that costs must be incurred now for the sake of providing benefits to future generations. Of course, these expenditures do impose a cost on future generations in terms of lower productive capacities. Also, ethical systems of some cultures and religions have very strong beliefs about intergenerational equity that need to be considered.

To avoid confusing many important issues we have thus far refrained from discussing time discounting. However, one of the most frequently used approaches for evaluating policy impacts on future generations is to convert them to present value terms. This involves considerations relating to the discount rate that are beyond the scope of this chapter. We should note, however, that the choice of the discount rate implicitly or explicitly implies some value judgement about intergenerational equity (see, e.g., Nordhaus, 1982). It also spills over into issues of international equity in that some cultures (e.g. Islamic) and some ideologies (e.g. socialism) have strong convictions about the appropriate level of interest rates that differ from the views of much of the rest of the world (see d'Arge, 1989).

The policy analysis of future emissions may differ from that of cumulative emissions in terms of adjustments to other reference bases; that is, policy-makers may not wish to confine their attention to the current generation. We have noted the appropriate adjustments for the future in table 3. Modifications are relevant to all reference bases except

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18 Other aspects of the refinement of resource valuations in the context of environmental policy, especially deforestation, are addressed by da Motta *et al.* (1991).

19 In the context of investments in environmental quality, it need not be incompatible with investment in economic growth. In the global warming context, this view has even been espoused by those not typically associated with the sustainable development school (e.g. Schelling, 1991).

Table 3

DYNAMIC REFERENCE BASES FOR CO_2 TRADEABLE ENTITLEMENTS

Reference base	*Applicability to equity criteria* [a]	*Operational measure*	*Ideal measure*
Economic welfare	Horizontal, Vertical, Ability, Compensation, Maximin	Future per capita GDP	Future per capita AGDP [b] (adjusted for purchasing power parity)
Population	Egalitarian (Consensus)	Future population	Future population (adjusted to discourage growth)
Land area	n.a. [c]	n.a.	n.a.
Energy use	(Vertical, Environmental)	Future Btus (adjusted for carbon equivalence)	Future Btus (adjusted for change in value and fuel efficiency)
Energy reserves	(Horizontal, Vertical, Compensation)	Future Btus (adjusted for carbon equivalence and change in value)	Future Btus (adjusted for change in value and fuel efficiency)
CO_2 emissions	Sovereignty, Environmental, (Horizontal, Vertical)	Future emissions (adjusted for carbon equivalence)	Future emissions (adjusted for carbon equivalence and fuel efficiency)

Source: Table prepared by the author.
a Parentheses indicate applicability is weak.
b Refers to GDP enhanced by non-market goods and services, primarily environmental.
c Not applicable since future land area changes cannot be anticipated.

land area. As in the previous subsection, emissions considerations would, in most cases, be combined with another reference base for the implementation of the various equity criteria. In addition, factors like the change in the value of reserves would enter into the cost-benefit calculus of welfare changes. Other options would be to include consideration of necessary and unnecessary emissions. In this case, as in others, there is nothing wrong with using a combination of ethical judgements as long as it is done in full understanding of the implications.

The effect of including future dynamic elements would probably be to shift the allocation of entitlements in favour of developing countries. Again, most of the influence is through the cost-side of the ledger. In cases such as consensus equity, however, this result is attributable to the rising relative political and economic stature of the third world.

E. Policy implications of alternative criteria

1. *The base case*

We will first examine the equity implications of the most frequently mentioned global warming mitigation strategy - that of a 20 per cent reduction in CO_2 emissions over projected baseline levels by the second or third decade of the next century. Several sharing arrangements have been proposed for such a policy. The one most often mentioned applies this reduction requirement to industrialized nations, and simply calls for a slowing or capping of current emission levels for developing countries (see, e.g., Chapman and Drennen, 1990; and Chandler, 1990).

However, we suggest that a more straightforward starting point for our analysis would be the case of equal abatement requirements (allocation of entitlements in direct proportion to emissions). Implicitly, this corresponds to the implementation of the sovereignty equity criterion[20]

Our analysis is undertaken for eight countries or country groupings, representative of various levels of development listed in column 2 of table 4. The table also lists corresponding measures of economic well-being in terms of per capita income, and energy resource endowments in terms of fossil fuels. The former are intended as a reference basis for evaluating several measures of equity, while the latter can serve as both a reference basis and an important indicator of mitigation costs (see also appendix table A).[21]

Columns 4 and 5 of table 4 list rough estimates (on a 1 to 10 scale) of environmental damage avoided through GHG mitigation, and the associated costs, respectively. At this stage of scientific inquiry the numbers are of course crude, but are nevertheless able to indicate the general tenor of policy impacts. The environmental damage avoided is based on assessments of the effects of climate change on agriculture, recreation and tourism, and sea level rise. For example, environmental damage is evaluated as being "small" for Canada, since a warming of its climate would increase agricultural productivity and would considerably offset the damage due to sea level rise and loss of recreational benefits and tourist revenues. At the same time, some of the more populated areas of Europe and Indonesia could be inundated by a fairly modest melting of the polar ice caps. A summary of damage estimates is presented in appendix table B.

Mitigation costs are evaluated in terms of actual direct expenditures, general equilibrium effects, and opportunity costs. Nations with large endowments of fossil fuels, especially coal resources, might be able to shift away from them to other energy inputs, but not without an adjustment cost and not without forgoing the opportunity to burn the lower cost fuel. This is the reason for the "large" estimate of costs for China, in contrast to the "small" level of costs for Central Africa. A summary of control cost estimates is presented in appendix table C.[22]

The net change in national welfare is presented in column 6 of table 4. The initial circumstances of the world regions analysed are the main reason for the variation in impacts. Countries such as Canada and the former Soviet Union are net losers, Western Europe, Brazil, Indonesia, and China stand to gain, and welfare in the United States and Central Africa remains unchanged.

The preceding analysis reflected country emission reductions based on a pure sovereignty equity principle that required equal percentage emission reductions for all countries. It is consistent with an allocation of entitlements representing an equal proportion of some baseline emissions for each country. However, the example has not yet included the feature of entitlement trading. Trading will take place as long as some countries have marginal abatement costs greater than or equal to the world market price of entitlements and some countries have abatement costs less than or equal to this price. It is usually assumed, and generally borne out by the cost studies cited in appendix table C, that abatement costs are relatively higher in developed than developing countries. Trading will thus lower the total costs to the former and provide a transfer to the latter, which in effect also lowers the net abatement costs of developing countries.

The trading feature of our policy proposal is illustrated in the last two columns of table 4. Data on cost saving through trading are tenuous at best, and we offer our numbers only for purpose of illustration (additional estimates, associated with other allocations, are presented in chapters VI and VII below). We suggest that industrialized countries could lower their net costs by as much as 38 per cent, in the case of the United States, by purchasing entitlements, and as much as 43 per cent in the case of the former Soviet Union. Entitlement payments could lower the net abatement cost by as much as 100 per cent

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20 The horizontal equity criteron is based on equal changes in ***welfare***, which, given differential abatement costs, would require differential abatement levels.

21 The characterization of energy resource status depends on both the reserve base and current reliance on fossil fuels. Thus, Western Europe's energy resources are characterized as only above average despite per capita fossil fuel reserves greater than those of China.

22 Some have commented that the estimates of abatement costs for Europe are too low. They support their claim with the rather reasonable statement that European nations have been leaders in fuel efficiency and thus, having exhausted most of the costless abatement associated with conservation, are confronted with only expensive options. Unfortunately, the studies we examined do not bear this out. Direct and indirect control cost estimates in general are critiqued by Rose (1989) Morris *et al.* (1990) and Darmstadter and Plantinga (1991).

Table 4

CHANGES IN NATIONAL WELFARE DUE TO BASE CASE TRADEABLE ENTITLEMENTS POLICY

Country (area)	Per capita GDP [a]	Energy resources [b]	Environmental damage avoided		Without trading: Cost		Without trading: Net change	With trading: Cost	With trading: Net change
United States	Rich ($20,725)	Rich (732/7.0)	Large	(8)	Large	(8)	0	5	3
Canada	Rich ($18,648)	Above average (304/6.0)	Small	(3)	Above average	(6)	-3	5	-2
Western Europe [c]	Rich ($14,322)	Above average (188/3.0)	Very large	(10)	Above average	(6)	4	4	6
Soviet Union	Above average ($3,491) [d]	Rich (724/4.3)	Small	(3)	Large	(7)	-4	4	-1
Brazil	Below average ($2,167)	Below average (21/0.4) [e]	Large	(7)	Average	(4)	3	2	5
Central Africa [f]	Poor ($475)	Average (88/0.3)	Small	(2)	Small	(2)	0	0	2
Indonesia	Poor ($527)	Average (33/0.2)	Very large	(9)	Small	(3)	6	2	7
China	Poor ($375)	Rich (103/0.6)	Above average	(6)	Average	(5)	1	2	4

Source: Calculations by the author.

a Data for 1989 from World Bank (1991).

b Figure at left is proved reserves of all fossil fuels per capita in 1990 in ton oil equivalent; figure at right is consumption of all fossil fuels per capita in 1990 in ton oil equivalent. Basic data and conversion factors obtained from British Petroleum (1991).

c Western Europe includes the European Community countries: Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain and the United Kingdom.

d Data for 1988 from Euromonitor (1991).

e Figure for consumption of fossil fuels per capita for Brazil is from the United Nations (1991), *1989 Energy Statistics Yearbook* (ST/ESA/STAT/SER.J/33), Sales No. E/F 91.XVII.3, New York.

f Central Africa includes: Burundi, Cameroon, Central African Republic, Congo, Equatorial Guinea, Gabon, Rwanda and Zaire. Energy resource figures are for total Africa.

for Central Africa and by large amounts for other developing countries. These results add two more areas (the United States and Central Africa) to the plus side of the net welfare change ledger. To the extent that we may have underestimated the cost saving to Canada and the former Soviet Union, there is a possibility that they may not suffer a net loss in welfare either. To the extent that we may have underestimated the transfer to developing countries, their net abatement cost may be ***negative***, thereby always assuring them of a welfare gain.

2. *Scenarios incorporating dynamic considerations*

We now analyse the implications of two alternative cases and compare them to the base case. They include a situation in which the stock nature of CO_2 and other GHGs is taken into account, i.e. the cumulative effect of previous emissions is factored into the equity calculus. We also examine the implications of the impact of mitigation policies on future generations, especially with regard to developing countries. Again, we analyse the implications of a 20 per cent reduction in emissions by the third decade of the next century, simply considering an alternative sharing of the emission reduction burden in general, and an alternative initial allocation of entitlements in particular.

To facilitate the comparison we present the results of all three cases in table 5. The environmental damage avoided by mitigation measures, which is constant in all three cases, is not shown (see again table 4). The three scenarios simply differ in the costs associated with different allocations. In effect, our base case is referred to as the current reference case, with some dynamic considerations taken into account in the cumulative and future cases.

In the cumulative emissions case, for a long-standing industrialized area such as the United States, we impose a 5 per cent surcharge on the basic 20 per cent emission reduction, thereby increasing abatement costs by 25 per cent. Slightly lower surcharges are imposed on Western Europe and the former Soviet Union. A more recently industrialized and smaller economy, such as Canada, is not assessed any cumulative penalty. On the other hand, emission reduction requirements for developing countries are simulated in the range of 50 per cent to 75 per cent of baseline. In this case, the net results (before any trading) show the former Soviet Union, Canada and the United States as net losers. The overall well-being of all other nations is improved.

Note that once we include the entitlements trading feature, the costs for all nations go down. In fact, for Central Africa they become negative as the volume of the transfers exceeds domestic abatement expenditures. Overall, one country's net welfare change shifts to the plus side of the ledger and all nations are better off than without trading.

In the future reference case, the costs for industrial nations, with the exception of the former Soviet Union, which also suffers from high opportunity costs because of its need to make an economic recovery, are the same as in the current reference (baseline) case. However, the uniform 20 per cent reduction in emissions over time is seen as significantly stifling economic development and a rebound of the Soviet economy, thereby incurring a sizeable opportunity cost of between 50 and 100 per cent in developing countries (see the discussion in section D). Accordingly, China and Central Africa join Canada and the former Soviet Union as net losers, while the net welfare gains in Ind nesia and Brazil are significantly reduced with respect to the other two cases. The qualitative results for the United States, Western Europe and Canada are the same as in the base case.

What is the effect of entitlement trading? The relatively higher abatement costs for developing countries have the effect of raising entitlement prices, resulting in less trading than in the current or cumulative reference cases.[23] Therefore, the opportunities for cost reductions are lower for all nations. Qualitatively, the post-trading results are the same in the other two cases, but overall world welfare is lower owing to a combination of higher abatement costs and fewer gains from trade.

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23 This is reflected in, for instance, the cost reduction through trading. For the United States, for example, the cost reduction for the future reference case is 2, as compared with a reduction of 4 for the cumulative reference case. If there were no cost curve shift, all the post-trading abatement levels would be the same. Net abatement costs would differ between cases, however, because of differences in transfers.

Table 5

CHANGES IN NATIONAL WELFARE DUE TO DYNAMIC BASE CASE TRADEABLE ENTITLEMENT POLICIES

	Current reference case				*Cumulative reference case*				*Future reference case*			
	Without trading		*With trading*		*Without trading*		*With trading*		*Without trading*		*With trading*	
Country (area)	*Cost*	*Net*	*Cost*	*Net*	*Cost*	*Net*	*Cost*	*Net*	*Cost*	*Net*	*Cost*	*Net*
United States	8	0	5	3	10	-2	6	2	8	0	6	2
Canada	6	-3	5	-2	6	-3	4	-1	6	-3	5	-2
Western Europe	6	4	4	6	7	3	4	6	6	4	5	5
Soviet Union	7	-4	4	-1	8	-5	5	-2	9	-6	5	-2
Brazil	4	3	2	5	3	4	1	6	6	1	2	5
Central Africa	2	0	0	2	1	1	-1	3	4	-2	1	1
Indonesia	3	6	2	7	2	7	1	8	5	4	2	7
China	5	1	2	4	3	3	1	5	10	-4	3	3

***Source*:** Calculations by the author.

Not surprisingly, there are significant differences in outcome among the three cases in the absence of trading. This implies different levels of cooperation, and different alliances are likely as policies vary. However, entitlement trading results in a remarkable similarity in outcome. We turn now to an examination of the extent to which these results hold good for equity principles other than sovereignty.

3. *Comparison of alternative dynamic equity criteria*

All three cases examined thus far are examples of the application of the sovereignty equity criterion only. Since space does not allow us to examine all criteria and time reference bases, we shall therefore confine our attention to the Compensation principle and the Rawlsian Maximin principle. Both of these equity criteria have a solid base. The Compensation principle is based on the Pareto rule that a policy should not be implemented if anyone is made worse off by it. The Rawlsian criterion singles out especially poor countries (referred to by the United Nations as "least developed"),[24] and is therefore consistent with the themes of development assistance.

Confining our attention to dynamic reference bases, our judgement is that they have greater merit than the use of the current reference base for several reasons, such as the argument of past responsibility and the reality of future opportunity costs. It should also be recalled that the dynamic reference bases provide more favourable allocations to developing countries in the case of several of the equity criteria.

In the case of Compensation we use the equal emission reduction reference base as a starting point and apply compensation to the results after trading. Therefore, the first two sets of columns in table 6 are the same as their counterparts in table 5. Canada and the former Soviet Union are both net losers under the cumulative reference case, with a net welfare change index of -1 and -2, respectively. An equivalent amount of compensation must be generated and transferred to them. One could conceive of all countries in the net gain column contributing to this effort; however, for all practical purposes, compensation is more likely to emanate from the industrialized nations alone. In the third set of columns in table 6 we have indicated that compensation with an index of -1 would have to be forthcoming from the United States and Western Europe to offset the losses to Canada and the former Soviet Union. The compensation index numbers are lower than the recipients' numbers because the index is specified in percentage terms, that is, the sum total of the outflows is a smaller percentage of the donor country's base welfare than of the recipient's base welfare. The net welfare of each of the four countries with per capita GNPs below the world average is unaffected by this policy in the cumulative reference case as in the future reference case.

The overall results are similar in the future reference case. Again, the first two sets of columns in this context correspond exactly to those in table 5. The levels of compensation are nearly the same as in the cumulative reference case. There is some small difference in net welfare after the transfers in that Western Europe's net welfare is lower than in the cumulative reference case. It appears that the initial differential cost effect is nearly offset by the lower trading effect (again due to the upward shift in the abatement cost curve of third world countries with development opportunity costs). However, this conclusion may not necessarily be open to generalization.

The results of the application of the dynamic Rawlsian criterion are presented in table 7. Under the cumulative reference case the cost estimates of column 1 reflect an allocation of emission entitlements skewed heavily in favour of the two developing countries and the country grouping classified as "poor" in table 4. The increase in their entitlements is borne by the two countries and the country grouping designated as "rich".[25] We have chosen to leave the entitlement levels for the two intermediate nations at their base levels. Not surprisingly, the net outcome of this allocation has the United States and Canada, along with the former Soviet Union, suffering significant decreases in welfare, and Western Europe near the break-even level. Trading helps considerably, especially for those countries, such as the United States, that have high marginal

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24 As of 31 December 1991, there are 47 countries in this category, according to the United Nations classification.

25 We have had to breach the top of our 1-10 scale to illustrate this case. Note also that we are implicitly using per capita GNP as a reference case (i.e. inverted) as the basis for allocating entitlements. To the extent that this scale is correlated with per capita emissions, we could have used the latter.

Table 6

CHANGES IN NATIONAL WELFARE DUE TO DYNAMIC TRADEABLE ENTITLEMENT ALLOCATIONS WITH COMPENSATION

	Cumulative reference case						*Future reference case*					
	Without trading		*With trading*		*After compensation*		*Without trading*		*With trading*		*After compensation*	
Country (area)	*Cost*	*Net*	*Cost*	*Net*	*Comp.*	*Net*	*Cost*	*Net*	*Cost*	*Net*	*Comp.*	*Net*
United States	10	-2	6	2	-1	1	8	0	6	2	-1	1
Canada	6	-3	4	-1	1	0	6	-3	5	-2	2	0
Western Europe	7	3	4	6	-1	5	6	4	5	5	-1	4
Soviet Union	8	-5	5	-2	2	0	9	-6	5	-2	2	0
Brazil	3	4	1	6	0	6	6	1	2	5	0	5
Central Africa	1	1	-1	3	0	3	4	-2	1	1	0	1
Indonesia	2	7	1	8	0	8	5	4	2	7	0	7
China	3	5	1	5	0	5	10	-4	3	3	0	3

Source: Calculations by the author.

abatement cost curves. The transfers also help the developing countries, two of which are able to attain the highest welfare change levels of any of the cases discussed thus far. Still, unlike the example of the Compensation principle, two nations suffer net losses.

In the future reference case, the higher opportunity costs of the developing countries are offset by an even greater allocation of entitlements to this group, again at the expense of the three OECD countries and at even higher levels.[26] The net result is even more negative for the three "rich" nations, with none of them gaining in welfare in the absence of trading.

With entitlement trading, the results are dampened somewhat, but still three countries are net losers. Again the potential trading opportunities are stunted somewhat by higher opportunity costs for developing countries, as reflected in an upward shift of their marginal abatement cost curves. The higher cost burden of the United States makes it relatively more desirable for it to buy CO_2 emission entitlements, but this is set against the likelihood that countries like China would be willing to sell relatively fewer, even at the higher world equilibrium price.

F. Conclusions

This chapter has analysed several equity principles in terms of their implications for allocating tradeable entitlements for CO_2 abatement. Each principle was carefully defined and its underpinning discussed. We also drew distinctions between their transformation into equity criteria, operational rules and the various reference bases against which they could be benchmarked. Several numerical examples were presented to illustrate the implications of three of the criteria for the net welfare of a representative sample of developing and industrialized nations. We emphasize that we make no claims as to the accuracy of our numerical results but suggest that they offer valuable insights into general tendencies.

It is not the place of this chapter to identify a single best equity criterion. This may leave some readers uneasy about its open-endedness. We therefore offer the following summary of some of the boundaries that might be relevant in making a final choice.[27]

Since a CO_2 agreement cannot be forced it will have to be reached by voluntary agreement, thereby giving Consensus equity some primacy. The importance of maintaining good North-South relations means that the cumulative and future reference bases[28] are likely to receive priority over the current reference base. If nations of the world do not wish to stifle the development effort of the third world, and the economic transition of the former Soviet Union and various Eastern European countries, Compensation will also be required. Pragmatism, if not altruism, will dictate that the compensation should come from industrialized nations so the outcome may not go as far as being Rawlsian, but will correspond to Vertical Equity, as well as Ability to Pay. Even Market Justice will be represented if a tradeable entitlements scheme is put into effect. The most appropriate reference base stemming from these conditions is inverse GDP. The extent of the inversion depends on Compensation needs, donor nation Ability to Pay and considerations of Vertical

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26 It will be recalled from section D.1. that empirical estimates of the reallocation due to the cumulative reference base were relatively low. We have assumed that the reallocation due to development opportunity costs is relatively higher.

27 The discussion that follows is based to a great extent on the insights of Ronaldo Seroa da Motta, who served as a discussant for this chapter at the UNCTAD Expert Workshop on a Global Scheme for Tradeable Carbon Emission Entitlements, Geneva, October 1991.

28 These two reference bases are mutually exclusive and could both be used. Also, as suggested by several analysts (see, e.g., Grubb and Sebenius, 1991; and Solomon and Ahuja, 1991), a combination of equity criteria might be the best course. Finally, a brief assessment of the distributional impacts of some of the equity principles not simulated here is presented in Rose (1990).

Table 7

CHANGES IN NATIONAL WELFARE DUE TO DYNAMIC RAWLSIAN ENTITLEMENT ALLOCATIONS

	Cumulative reference case				*Future reference case*			
	Without trading		*With trading*		*Without trading*		*With trading*	
Country (area)	*Cost*	*Net*	*Cost*	*Net*	*Cost*	*Net*	*Cost*	*Net*
United States	12	-4	7	1	14	-6	10	-2
Canada	8	-5	6	-3	10	-7	8	-5
Western Europe	9	1	5	5	10	0	7	3
Soviet Union	8	-5	5	-2	9	-6	6	-3
Brazil	3	4	1	6	6	1	4	3
Central Africa	0	2	-3	5	1	1	-1	3
Indonesia	1	8	-2	11	1	8	-1	10
China	1	5	-3	9	1	5	-2	8

Source: Calculations by the author.

Equity. Again, to the extent that per capita emissions are correlated with inverse GDP, this reference base could be used as a proxy.

We would reiterate that the trading feature of the policy instrument we are proposing negates some of the differences among various equity criteria. With the exception of the future reference case (in which there is an upward shift in the abatement cost curves of developing countries), post-trading abatement levels will be the same, for a given nation, over most of the criteria. Total costs will differ because they are the sum of abatement costs and entitlement costs. However, to the extent that control costs are generally lower for developing countries, the direction of resource transfers through entitlement purchases will reinforce such criteria as Vertical Equity, Rawls' Maximin and Ability to Pay.

The author has no illusions that this chapter will resolve the debate on how to reach agreement on mitigating global warming.[29] It is hoped, however, that the illustration of implications of alternative equity criteria will serve as an important step towards finding a solution to the potential threat to the global commons. The fact that there are several alternative definitions of equity should not be a reason for dismay, but rather a stimulus to further study. In principle, nearly all nations subscribe to some concept of fairness, and thus its potential as a unifying principle should not be neglected.

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29 Several factors have previously hampered the implementation of equity criteria in many contexts. One major obstacle has been the actual measurement of the direct and indirect distributional impacts of public policies. However, the recent refinement of data and specifications of new models should help to overcome this problem (see, e.g., Sawyer, 1979; Ballard *et al*., 1985; and Rose *et al*., 1988).

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Appendix to Chapter V

Appendix table A

REFERENCE BASES FOR TRADEABLE CO_2 ENTITLEMENTS

Country	GDP	GDP per capita	Private consumption
	Millions of dollars	Thousands of dollars	Per cent of GDP
Brazil	319,150	2.2	65.0
Canada	488,590	18.6	59.0
Central Africa [a]	33,330	0.5	70.0
China	417,830	0.4	59.0
Indonesia	93,970	0.5	53.0
United States	5,156,440	20.7	67.0
Soviet Union	998,400	3.5	n.a.
Western Europe [b]	4,714,830	14.3	59.5

Source: World Bank (1991), *World Development Report, 1991* (New York: Oxford University Press).

Country	Population	Population subset	Projected population 2025	Land area
	Millions mid-1989	Millions aged 15-64 years	Millions	Thousands of square kilometres
Brazil	147.3	88.5	236	8,512
Canada	26.2	17.8	32	9,976
Central Africa [a]	70.2	35.7	189	4,353
China	1,113.9	745.2	1,566	9,561
Indonesia	178.2	105.7	282	1,905
United States	248.8	164.4	316	9,373
Soviet Union	288.0	n.a.	307	22,402
Western Europe [b]	329.2	218.6	337	2,368

Source: World Bank, *op. cit.*

Country	Energy consumption	Energy consumption per capita	Energy reserves			
	Thousand tons of oil equivalent	Ton oil equivalent per capita	Billion tons of oil equivalent			
			Coal	Gas	Oil	Total
Brazil	61,859	0.4	2.8	0.1	0.4	3.3
Canada	169,819	6.5	4.5	2.4	0.8	7.7
Central Africa [a]	4,660	0.1	41.7 [c]	6.9 [c]	8.0 [c]	56.6 [c]
China	615,190	0.6	111.3	0.9	3.3	115.5
Indonesia	33,948	0.2	2.0	2.3	1.1	5.4
United States	1,681,890	6.8	162.0	4.3	3.6	169.9
Soviet Union	1,278,533	4.4	160.0	39.0	7.9	206.9
Western Europe [b]	998,624	3.0	47.8	2.7	0.9	51.4

Source: For energy consumption: United Nations (1991), *1989 Energy Statistics Yearbook* (ST/ESA/STAT/SER.J/33) (New York). For energy reserves: British Petroleum (1990), *BP Statistical Review of World Energy* (London: June); PennWell Publishing Co. (1989), *Oil and Gas Journal*, 25 December.

a Central Africa includes: Burundi, Cameroon, Central African Republic, Congo, Equatorial Guinea, Gabon, Rwanda and Zaire.

b Western Europe includes the European Community countries: Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain and the United Kingdom. Data on GDP, GDP per capita and Private consumption in Western Europe are from Euromonitor (1991), *European Marketing Data and Statistics 1991* (London: Euromonitor Publications, Ltd.).

c Figures on energy reserves are for total Africa.

Appendix table B

QUALITATIVE ESTIMATES OF DAMAGES FROM GLOBAL WARMING

Country	*Sea level rise*	*Recreation/ tourism*	*Agriculture*
Brazil	Moderate damage	Heavy damage	Neutral
Canada	Light damage	Light damage	Minor benefit
Central Africa	Neutral	Neutral	Light damage
China	Heavy damage	Light damage	Neutral
Indonesia	Heavy damage	Moderate damage	Neutral
United States	Moderate damage	Moderate damage	Light damage
Soviet Union	Light damage	Light damage	Minor benefit
Western Europe	Heavy damage	Moderate damage	Light damage

Source: Easterling *et al.* (1989); Hekstra (1989); Mabbutt (1989); Parry and Carter (1989); Vellinga and Leatherman (1989).

ESTIMATES OF THE COST OF CO_2 MITIGATION

Country/region	*Investigator*	*Methodology*	*Time Period*	*Cost of control (per ton carbon equivalent)*	*Strategy characteristics*
Global	Whalley and Wigle (1991)	CGE model	1990-2030	$430 for 50 per cent	Combination of six different regions that impose the same rate of carbon taxation
Global	Nordhaus (1991)	Dynamic mathematical progamming		10-$430 for 5-98 per cent	Incorporation of four end-use sectors, various fuels and potential production techniques
Global	Nordhaus (1991)	Survey of results of various estimates		5-$342 for 10-80 per cent	Combination of reduction of CO_2, CFCs and forestry options
United States	Manne and Richels (1991)	Macroeconometric	2020 2040	$600 for 20 per cent $250	1 per cent autonomous conservation; carbon taxes and regional trade in emission rights
OECD (except United States)	Manne and Richels (1991)	Macroeconometric	2020 2040	$200 for 20 per cent $250	5 per cent autonomous conservation; carbon taxes and regional trade in emission rights
Soviet Union and Eastern Europe	Manne and Richels (1991)	Macroeconometric	2020 2040	$600 for 20 per cent $700	25 per cent autonomous conservation; carbon taxes and regional trade in emission rights
China and Rest of World	Manne and Richels (1991)	Macroeconometric	2020 2040	$40 for doubling $250	1 per cent autonomous conservation; carbon taxes and regional trade in emission rights
United States	Chandler (1990)	Direct estimation	2020	$118 for 20 per cent	Energy efficiency and development of additional energy supplies
Soviet Union	Chandler (1990)	Direct estimation	2005	$16 for emission control	Structural changes, energy efficiency and interfuel substitution
Poland	Chandler (1990)	Direct estimation	2005	$8 for 20 per cent	Structural changes, energy efficiency and interfuel substitution
United Kingdom	European Community (1990)		2005	10-$140 for 10-30 per cent	Reduction of CO_2 emissions from the energy sector
(Eastern Europe, OECD)	Barbier *et al.* (1990)			$60 for 50 per cent	Potential reduction in CO_2 and CFCs
Sweden	Bodlund *et al.* (1989)			160-$250 for 63-74 per cent	CO_2 reduction in the electric power sector and the sectors using electric power
Netherlands	Kram *et al.* (1989)	Linear programming		$40 for 28 per cent	
Egypt	Blitzer *et al.* (1990)		2002	$200-$3135 for 15-50 per cent	Substitution is restricted to oil and gas
Brazil, Indonesia and Cote d'Ivoire	Houghton *et al.* (1987)	Direct estimation		$2.3/ton (Brazil) $15/ton (Indonesia) $8/ton (Cote d'Ivoire)	Curtailment of deforestation

Source: See the relevant References at the end of this chapter.

Chapter VI

'ACCEPTABLE' ALLOCATIONS OF TRADEABLE CARBON EMISSION ENTITLEMENTS IN A GLOBAL WARMING TREATY

Scott Barrett*

INTRODUCTION

The idea of employing a system of tradeable carbon emission entitlements (TCEEs) in a climate change treaty is appealing for two main reasons. The first is that such a system could, if certain assumptions hold, result in cost-effective abatement by signatories (that is, the total cost of achieving any overall ceiling on emissions could be kept as low as possible). The second is that trading results in transfers of resources, and if the initial allocation favoured countries less able (and perhaps also less willing) to pay for abatement, then resources would flow to these countries from countries more able (and perhaps also more willing) to pay for it. In other words, a system of TCEEs could achieve the twin objectives of international efficiency and equity in a global warming treaty.[1]

Whether a system of TCEEs will result in cost-effective abatement depends on how such a system is designed, and on the structure of the market. This issue is explored in chapter VIII. Furthermore, whether such a system will result in an outcome that is in some sense "equitable" depends partly on how "equity" is defined, a matter discussed in chapter V. The purpose of the present chapter is to determine whether allocation methodologies exist that would be "acceptable" to a large number of countries. The answer to this question depends in turn on the cost effectiveness of a TCEE system, and on notions of equity.

This chapter assumes that a system of TCEEs, if implemented, would work perfectly in the sense that all potential gains from trade would be exhausted. While this might seem to be a very strong assumption, and one that would make a system of TCEEs appear extremely attractive to negotiatiors, depending on how permits are allocated initially, and how negotiators agree on allowable emission levels, even this assumption will not guarantee that a significant number of countries will want to agree to a global warming treaty using TCEEs. Some countries may prefer to remain outside the agreement. What is more, signatories may choose emission levels that are suboptimal in the sense that net benefits for the group of signatories are not maximized. In other words, the assumption about

* London Business School, London.

1 Of course, there are other means of achieving these objectives. For example, an internationally coordinated carbon tax could also minimize the costs of abatement by signatories to a climate change treaty, and a redistribution of a part or all of the tax receipts could induce countries less able (willing) to fulfil the treaty obligations to accede to the treaty. This chapter does not compare approaches, but considers only the TCEE mechanism.

"perfectness" in trading does not imply that agreement will be easy to reach or very effective.

As noted in chapter V, there are many equity criteria, and it is by no means obvious which is best, even if implementation were to pose no problem. However, accession to a climate change treaty will be voluntary, and hence it is especially important to assess the effects of any given equity criterion on participation. To take a simple example, a rule that entitles every citizen to the same level of CO_2 emissions might have some ethical appeal, but analysis by Barrett (1991c) suggests that the rule may not be acceptable to the countries with high emissions per capita, assuming countries pursue self-interest (this result is confirmed later in this chapter). If that is so, countries with low emissions per capita will not want to join the treaty, for transfers to these countries may then be so small as to make accession unattractive to them. But the outcome will then be that no agreement is reached, and that outcome might not be viewed as being equitable - not least because some countries will be better able to cope with the environmental damage resulting from climate change than others.

Even allowing countries to pursue their self-interest can result in an outcome that is in some sense "fair." Since accession to a treaty is voluntary, and since the rich countries have a particular interest in having the poor participate in a treaty, the rich have an incentive to offer the poor countries a treaty proposal that makes them better off. The reason the rich countries want the poor to participate is that the former are likely to gain the most from the abatement of greenhouse gases, and hence have a greater incentive to abate their own emissions if negotiations fail, whereas poor countries are unlikely to undertake substantial abatement on their own. Hence, if negotiations fail, abatement can be achieved more cheaply at the margin in the poor countries. The rich countries will know this, and be particularly keen to propose a treaty that is attractive to the poor countries.

Another reason for believing that an acceptable allocation will be fair, even if countries pursue self-interest, is that equity principles can prove helpful in negotiating the initial allocation of TCEEs. As demonstrated later in this chapter, negotiations typically focus on simple rules for determining signatory obligations, and equity principles can supply candidate rules for a global warming treaty employing TCEEs; the equal per capita entitlement allocation is an example of such a rule.

It is important to note the different role played by equity here as compared with chapter V. In that chapter an allocation rule like equal entitlements per capita is seen to be attractive because of its ethical properties. Here it is assumed that countries pursue self-interest, but search for rules that can be used to allocate TCEEs. The potential attraction of a rule like equal entitlements per capita is not that it *is* equitable - countries pursuing self-interest do not care about a rule's ethical properties *per se* - but that it is a rule that is recognized by every party, and known to be recognized by every party, and so on. If the rule makes every party better off compared to the outcome in which there is no agreement, then countries may agree to employ the rule, with the consequence that a "fair" agreement is reached, even though the parties themselves did not purposefully seek a "fair" outcome.

While it is perhaps comforting to know that pursuit of self-interest can result in equitable outcomes, there is no certainty that parties will actually be able to agree on an allocation rule. What is more, global warming is a moral issue as much as it is a scientific or economic one. Whatever action is taken (or not taken) will have implications for the distribution of well-being both across countries and over generations. Hence, moral reasoning should - and, I believe, will - play a role along with science and economics in guiding decision-making.

This much is uncontroversial. More difficult is the task of identifying responsibilities and operationalizing moral reasoning in a way that does not seem idealistic. This chapter will consider the role moral reasoning can play in negotiations even while countries pursue self-interest.

This chapter and the next differ from the other chapters in this book in that the approach is analytical in nature. This chapter defines an "acceptable" allocation, and then asks whether any given allocation methodology would satisfy this definition. The analysis is not purely hypothetical, as an attempt has been made to ground it in empirical observation. Nevertheless, the analytics are kept simple - largely to lay bare the essential features - and the analysis can therefore be taken as indicative only. Hence, when one reads "China would not find this allocation acceptable," this statement should not be taken literally; rather, it should be seen to result from assumptions that underly the analytics and that, as noted above, greatly

simplify a problem that is immensely complex.

It must also be emphasized that only a very special agreement is being examined here - an agreement that reduces carbon dioxide emissions from fossil fuels by means of freely tradeable carbon emission entitlements. It is most unlikely that such a system would be born from the opening negotiations. At best, it might emerge over a period of time, and be preceded by other, more modest agreements. The value of the analysis is that negotiators may need some guidance as to where a particular path may eventually lead. If it can be shown that a full-fledged TCEE scheme is wholly unworkable, then negotiators may decide to take a different tack. On the other hand, if such a scheme can be shown to have some potential, then negotiators may be led to design an initial agreement that could ultimately evolve to embrace international trading, even if the final form of such trading is as yet unknown.

In reading this chapter, a final point must be borne in mind, and that is that the analysis is limited to the problem of ***reaching*** an agreement employing TCEEs. Whether the agreement can be ***sustained*** is an important issue, because free-rider incentives are likely to loom large in the case of climate change. However, free-rider deterrence is a problem that must confront any approach to negotiating emission reductions. It is nevertheless not considered here since the purpose of this chapter is to see whether TCEEs could be allocated in such a way as to make broad agreement acceptable, and not to determine whether the agreement, once reached, could be sustained.[2]

The chapter begins with a discussion of some candidate allocation schemes that have been proposed previously. Section B provides a conceptual basis for evaluating these schemes, and section C analyses the proposed rules by employing this conceptual apparatus. The main findings are recapitulated in section D, Summary and conclusions.

A. Some candidate allocation rules

How should TCEEs be allocated? A number of proposals have been made, and this section considers a great many of these. Although the proposals are grounded in very different rationales, they share a common feature: they are all simple. This may seem surprising, given that the global warming problem is itself extremely complicated. It is perhaps best to begin, then, by asking why the proposals are simple, and whether this is a good thing.

1. *Focal points*

Suppose two countries must negotiate over an allocation scheme. Assume that the negotiators (labelled A and B) have agreed that they will use TCEEs in their treaty, and have already decided on the total quantity of TCEEs that will be made available. The only issue they have yet to agree on is how the given quantity of TCEEs is to be allocated.

Suppose further that the two negotiators, A and B, cannot communicate with each other. This assumption may seem odd, given that we are investigating a negotiation. However, the reason for making this assumption will shortly become apparent.

Assume to begin with that each party has no information about the other party. However, each party knows both will do better if agreement can be reached (whatever it is) than if no agreement is reached. Suppose now that the negotiators have only one chance to reach agreement. They each propose a quantity of entitlements to receive (without communicating), and if the quantities chosen by both negotiators sum to the agreed total quantity of TCEEs, then each one gets the quantity asked for; if not, no agreement is reached, and each party is made worse off.

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2 For an analysis of free-rider deterrence in a global warming treaty, see Barrett (1991e). Note that if mechanisms were built into an agreement to punish non-signatories, then this punishment would affect non-signatories' net benefits.

If you were negotiator A, what quantity would you ask for? While there is no correct answer, you would probably ask for one half of the total quantity of TCEEs agreed earlier. Negotiator B is likely to do the same.

Suppose now that each negotiator knows that country A has a population of 100 and country B has a population of 200. Then, if you were negotiating on behalf of country A, what quantity of TCEEs would you ask for? Again, many answers are possible, but it is likely that the negotiators will allocate TCEEs on the basis of population; and therefore that negotiator A will ask for one third of the total TCEEs available simply because country A's population is only one third of the total. Similarly, negotiator B is likely to ask for two thirds of the total TCEEs available.

Now suppose that each negotiator knows not only the total population but also the GNP; each knows that A has a GNP of 200 and B has a GNP of 100. The problem is now more complicated, and the decision harder. Negotiators might continue to split the sum evenly, or allocate TCEEs on the basis of population (one third for A and two thirds for B) as before. Alternatively, they might now allocate TCEEs on the basis of GNP, with B receiving twice as many TCEEs as A because B is half as rich in total. Perhaps the most likely outcome would involve the allocation of TCEEs on the basis of GNP per capita, with B receiving 80 per cent because it is one eighth as well-off as A (its GNP per capita is 0.5, while A's is 2).

One can see that, as the amount of information increases, the problem of reaching agreement without communication becomes more difficult, although simple rules are still employed to allocate the TCEEs. Suppose that the number of parties to the negotiation now increases to over 100, that, in addition to the above information, a number of detailed estimates are made available on abatement costs and benefits under a variety of scenarios using a number of different models and assumptions; that each party makes a plea for special treatment on the grounds of past actions to protect the environment or domestic difficulties; and so on. Then the outcome is even less obvious, although negotiators will probably still settle on one of the simple rules described earlier simply because the additional data confuse as much as they clarify. However, this is not always true. Suppose that a study commissioned jointly by the negotiating parties, or a study carried out by an independent authority, suggested a "reasonable" allocation formula that was based on science, or economics or ethics. Then it is possible that this new information might form the basis for agreement.[3]

It might be argued that this line of reasoning breaks down once communication between the negotiators is allowed, and all the information available can be discussed and analysed. However, this seems not to happen (see Schelling, 1960, for the seminal, and still absorbing, discussion on focal points). Experience in negotiating past international agreements suggests that the outcomes are almost always simple, even (one is tempted to say, especially) if the issue involved is complicated (see Barrett, 1991b). As a recent example, the original Montreal Protocol on Substances that Deplete the Ozone Layer required industrialized countries to reduce their consumption and production of CFCs by half (see Benedick, 1991, for a discussion of the negotiations). In implementing its obligations domestically, the United States Government allocated tradeable permits to United States producers and importers on the basis of past levels of production and imports (see EPA, 1988).[4]

While it seems reasonable to expect that an allocation rule will obey some simple formula, it is not at all obvious what that formula should be. As Schelling (1960, p. 69) observes, "The 'obvious' outcome depends greatly on how the problem is formulated, on what analogies or precedents the definition of the bargaining issue calls to mind, and on the kinds of data that may be available concerning the question in dispute." This means that there is a role for analysis - like that provided in section C - that can offer a framework for thinking about the allocation problem.

It is important to note that ethical rules often serve as focal points for negotiation.

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3 This is what happened in the Law of the Sea negotiations; see Sebenius (1991).

4 While the allocation rules were simple, the amended Montreal Protocol establishes an Ozone Fund, which transfers resources from industrialized countries to developing countries in order to compensate the latter for the "incremental costs" of complying with the agreement. Hence, this agreement employs side payments, and the allocation formula embodied in the Protocol should not be seen as acceptable to all parties in the absence of these side payments. This chapter assumes that side payments cannot be made. The assumption is restrictive but, if side payments are allowed, it is easy to devise an allocation formula that will win broad acceptance (see Barrett, 1991d). As noted in the introduction to this chapter, one virtue of TCEEs is that they result in transfers. These transfers serve roughly the same purpose as side payments. But transfers are unique to TCEEs. If allowance is also made here for side payments, this distinctive feature of TCEEs would be lost.

Recalling the earlier examples, focal points included "dividing the pie evenly," "allocating TCEEs equally among all people, irrespective of their nationality," and "allocating the TCEEs in inverse proportion to income per head." However, the outcomes that seemed compelling did not derive their attraction from their ethical properties. Rather, the ethical rules were known to each party, and were known by each party to be known by the other party, and so on. The ethical rules thus served as focal points.

2. *Discussion of some proposed allocation rules*

Table 1 summarizes most of the allocation rules that have so far appeared in the literature. Some of them cannot be implemented, and I shall begin by discussing these.

Rule 4 is too vague. Are no TCEEs to be allocated to industrialized countries? On what basis are TCEEs to be allocated to poor countries? Are middle income countries to be treated as rich countries or as poor? Although Rule 4 is too vague to be implemented, we shall see that other rules capable of implementation do end up favouring poor countries.

Rules 6 and 7 impose very heavy informational requirements. It is easy to choose a figure for abatement cost as a percentage of some base year's GNP, but it would be necessary to know each country's abatement cost function in order to determine the quantity of TCEEs the individual countries should initially be allocated. Similarly, one can choose a level of cost per unit of status quo emissions, but determining the quantity of TCEEs to be made available to a country under this rule requires a knowledge of that country's abatement cost function. While much research has been devoted to estimating abatement cost functions, model estimates vary, and detailed country-by-country estimates do not yet exist. Cost functions could be estimated for every country, but it is most unlikely that agreement on the "right" cost function will be easily won.

Like Rule 4, Rule 8 is not fully specified, because the question of how the auction revenues are to be employed (redistributed) is not addressed. The judgement of a number of commentators is that the rule is impractical (see Pearce, 1990, and Markandya, 1991).

Rule 9 is also problematic. First, while it may seem compelling to ensure that emissions of greenhouse gases do not exceed the environment's capacity to absorb these gases, stabilization of atmospheric concentrations of greenhouse gases would require a reduction of about 60 per cent in the emission of long-lived gases like CO_2, and all available evidence indicates that the cost of such a reduction would be huge. While this is one candidate for the choice of an overall emission level, it is not the only one, and it is not necessarily the best one (see Barrett, 1991c). Second, fixing the price at which trading takes place means that the market will not clear. Hence, some of the efficiency advantages of trading will be lost, and, as a consequence, countries are likely to agree to less ambitious obligations. Finally, while some mechanism is required to ensure that countries carry out their obligations, there is no international body with the authority to levy fines. The key ingredient to this proposal, however, seems to be that TCEEs should be allocated on the basis of population, and in this sense Rule 9 is similar to Rule 1. The analysis carried out later in this chapter considers Rules 1-3, 5, and 10-13 (plus an additional rule to be explained in section C).

A great many of these rules assume that the total limit on emissions is negotiated first, and that an allocation of the total is negotiated later. However, it is very unlikely that negotiations will develop in this way (Barrett, 1991c). The desirability of any given allocation scheme to any one country will depend on the total quantity of emissions abated. In other words, for any given allocation scheme, countries will have different views on the total quantity of emissions they would like to have abated. Hence, it is essential for the level of abatement to be determined ***jointly*** with the allocation scheme. This is the approach taken in section C below. The important point to note here is that it is not essential for a total level of emissions to be decided upon before an allocation scheme is chosen.

For example, Rule 1 can be taken to be a rule on the maximum quantity of CO_2 emissions per capita, rather than a rule for allocating a fixed quantity of emissions according to each country's share of the total population of all negotiating countries. Similarly, Rule 2 can be expressed as a ceiling on allowed emissions per unit of GNP, and Rule 3 as a uniform percentage reduction in each country's base year emission level.

Rule 5 is incompletely specified; it does not say how the different types of fossil fuel are to be weighted in arriving at a total figure.

Table 1

SOME PROPOSED ALLOCATION RULES

Rule	*Rationale*
1. Negotiate a global limit on CO_2 emissions, and allocate this limit on the basis of CO_2 emissions per capita.	"The moral principle is simple, namely that every human being has an equal right to use the atmospheric resource. The economic principle follows directly - those who exceed their entitlement should pay for doing so. The practical effect is obvious: it would require the industrialised world, with high per capita energy consumption, to assist the developing world with efficient technology and technical services" (Grubb 1989, p. 37). See also Pearce (1990), Bertram *et al.* (1989), Hibiki *et al.* (1989), and Burtraw and Toman (1991).
2. Negotiate a global limit on CO_2 emissions, and allocate this limit on the basis of CO_2 emissions per unit of GNP.	"...carbon emissions are tied to economic activity and the objective should be to maximise the efficiency of economic production" (Grubb, 1989, p. 36). Grubb argues that measurement of GNP would pose a problem, although Pearce (1990) maintains that countries do agree on the basis of GNP measures through the United Nations statistical system. Both Grubb and Pearce argue that this rule would discriminate against poor countries. Grubb (1989, p. 36) refers to the rule as "an untenable proposition".
3. Reduce emissions by a uniform percentage.	Minimal disruption to status quo ante, and hence smaller transfers. Common rule used in other international environmental agreements. Criticized by Grubb (1990, p. 36) on the basis that it would "reward the countries which are currently the most polluting".
4. Allocate entitlements to poor countries.	"Since the world's rich are the chief polluters of the atmosphere, there are strong equity (and some efficiency) grounds for allocating entitlements initially to the world's poor, so that the necessary purchase of entitlements by the world's polluters would generate a financial flow from rich to poor, hopefully providing resources to encourage development of the poor countries" (Bertram *et al.*, 1989, p. 14).
5. Allocate entitlements in inverse proportion to per capita consumption of fossil fuels.	"This would directly reward those countries which moved seriously to renewable energy, while at the same time helping countries with low levels of development and hence low total energy consumption" (Bertram *et al.*, 1989, p. 15).
6. Choose an overall level of cost to be borne by all countries, and then set each country's emission reduction so that abatement cost relative to pre-control income is the same for all countries.	Based on ability to pay (Burtraw and Toman, 1991).
7. Choose an overall level of cost to be borne by all countries, and allocate this cost in such a way that abatement cost relative to pre-control emissions is the same for all countries.	Based on "polluter pays" principle (Burtraw and Toman, 1991).
8. Agree on a total quantity of emission entitlements, and then have an international agency auction these off to the highest bidders.	TCEEs would be allocated to countries with the greatest willingness to pay. However, the resulting allocation is also likely to reflect ability to pay. Although the auction revenues might be used to address this problem, Pearce (1990) concludes that "it is unlikely that an auction approach to permits would be acceptable".
9. Set total emissions equal to the capacity of the environment to absorb greenhouse gases, allocate these on the basis of population, and set a fixed price on entitlement trades. Countries that emit in excess of their entitlements should be fined at a rate that exceeds the fixed price on entitlement trades.	"...sustainable development demands that human beings collectively do not produce more carbon dioxide ... than the earth's environment can absorb ... in a world that aspires to such lofty ideals like global justice, equity and sustainability, this vital global common should be shared equally on a per capita basis" (Agarwal and Narain, 1991, p. 13). "Fines should be ... given over to a 'global protection fund'. The fund can be used to assist these countries which are affected by climate destabilization and to develop technologies that will reduce greenhouse gas emissions. These technologies can then be used by all humankind. Such a system should provide an incentive to countries like India to keep their share of greenhouse gas emissions low and force countries like the USA to reduce their emissions rapidly - and, thus, all will join the race to save the planet" (Agarwal and Narain, 1991, p. 20).

Table 1 (concluded)

SOME PROPOSED ALLOCATION RULES

Rule	*Rationale*
10. Allocate TCEEs on the basis of land area.	"...would be easily defined and measured and would offer a disincentive to high population densities. But the absence of any link to human activities makes it impractical ... In short, the combination of a lack of any underlying ethical basis and perverse consequences in practice rule out this criterion" (Grubb and Sebenius, 1991, pp. 16-17).
11. Historical allocations, such as a cumulative limit on CO_2 emissions divided equally between industrial and developing countries, or cumulative emissions per capita.	Potential global warming damage is related to atmospheric concentration, which depends in turn on cumulative emissions (taking decay rates into account) rather than current emissions. "Historical responsibility as a principle for allocation possesses considerable intrinsic appeal, but regardless of the index chosen faces immense difficulties" (Grubb and Sebenius, 1991, p. 17).
12. Mixed and transitional allocation systems, such as a weighted average of population and current emissions, employed with a total emission target.	"...has many of the broad features of a per capita system, but ... carries the flexibility for negotiations to affect the scale of transfers implied by the allocation, without compromising the environmental target" (Grubb and Sebenius, 1991, p. 21).
13. Two-tier or multi-tier allocation schemes, whereby obligations are uniform within a group of countries, but not across different groups. For example, industrialized countries might face obligations based on current emissions, and poor countries might face per capita obligations.	Like Rule 12, this rule seeks to de-polarize negotiations by reducing transfers to a level that is acceptable to the industrialized countries and yet provides incentives for poor countries to participate in the agreement. See Barrett (1991c).

Source: Compiled by the author.

There are a number of possibilities. Total consumption could be calculated on a Btu basis, or on a monetary value basis. However, it seems most likely that the different fuels would be weighted according to their carbon content. If the latter is the case, then the rule requires that TCEEs be allocated in inverse proportion to per capita carbon emissions. In negotiations, countries choose an overall level of emissions on the understanding that this overall level will be allocated to the different negotiating countries in inverse proportion to their per capita carbon emissions.

Rule 10 is easily expressed as a maximum quantity of allowable emissions per unit of land area. Rule 11 could be expressed in different ways. One version would set a maximum quantity of cumulative emissions made available to every country from, say, 1950 onwards. Another, simpler version would involve choosing an overall emission level subject to a requirement that this total volume of TCEEs be allocated in inverse proportion to cumulative emissions. For example, if Country i had emitted 10 times as much CO_2 as Country j over the period 1950-1987, then Country i would receive one tenth as many entitlements as Country j.

Rules 12 and 13 differ from the rest in that they ***combine*** different focal points to arrive at an allocation formula. The reason for considering these rules is explained in section C.

The rationales for the various rules are given in table 1. As noted in the introduction to this chapter, the rationale behind each rule is not important to the analysis of the ***effects*** of using the rules. Depending on the criteria employed, some of the rules may seem fairer than others (see chapter V). However, for this chapter all that matters is that each rule has some rationale, and one that is recognized by each of the parties, and known to be recognized by each of the parties, etc.; that is, that each of these rules can serve as a potential focal point for negotiations.

B. Conceptual considerations

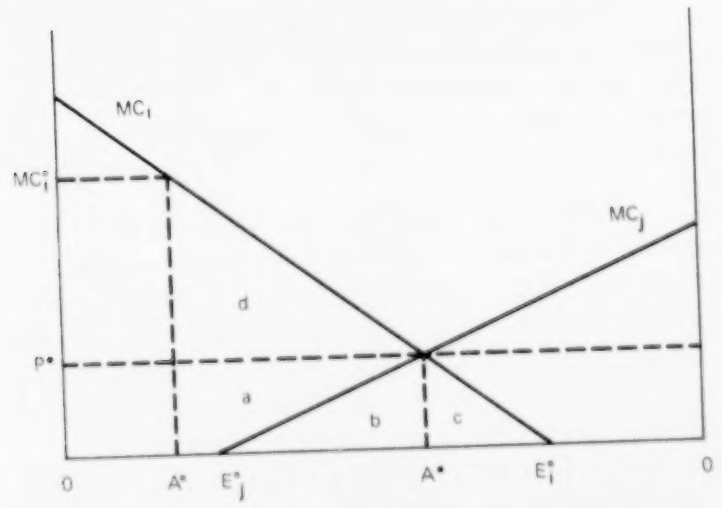
The purpose of this section is to provide a conceptual basis for evaluating whether a country will gain or lose under a given allocation formula. An understanding of this problem is absolutely critical to the assessment of alternative allocation formulas, because countries can always choose to remain outside an agreement, and probably will unless they can be assured of gaining in some real sense.

1. *A simple case*

Consider a simple example of allocating a fixed quantity of TCEEs between two countries, labelled i and j. Figure 1 illustrates the problem. The length of the horizontal axis measures the total quantity of TCEEs available. MC_i and MC_j are Country i and j's marginal cost of abatement curves. The status quo when neither country undertakes any abatement is identified by E_i^0 and E_j^0; these are the initial emission levels of the two countries. E_i^0 is measured from the left axis, and E_j^0 is measured from the right axis.

Figure 1

GRAPHICAL ILLUSTRATION OF MARKET EQUILIBRIUM AND GAINS FROM TRADE



***Source*:** Calculations by the author.

For both countries, the cost of abating the first unit of emissions is shown to equal zero. If no action is taken to abate carbon emissions, then by definition no abatement costs are incurred. To abate the first unit of emissions requires only a small change in, say, the fuel mix for a country, and the cost of such a change would be negligible (see Nordhaus, 1991). As more abatement is undertaken, however, the cost of abating successive units of carbon will rise. Since i's emissions are measured from the left axis, i's marginal abatement cost curve rises to the left of E_i^0. Likewise, since j's emissions are measured from the right axis, j's marginal abatement cost curve rises to the right. Assuming no fixed costs, total abatement costs are measured by the area under the marginal cost curves over the relevant abatement levels. Since E_i^0 and E_j^0 sum to more than the total quantity of TCEEs made available, some abatement will have to be undertaken if the total emission constraint is to be met; marginal and total abatement costs must be positive for at least one country.

Suppose the initial allocation of TCEEs is at point A^0. Then, if no trading takes place, Country i must bear a substantial cost in complying with its obligation (area $a+b+c+d$), while Country j bears no cost at all. This is consistent with the example in which entitlements are allocated on the basis of population. Country i has high emissions per capita, and Country j low emissions per capita. Country j can meet its obligation without trading at zero cost; it has a surplus of entitlements. However, Country i can meet its obligation without trading only by abating a substantial quantity of emissions (E_i^0 minus A^0, measured from the left axis).

Suppose now that trading in TCEEs is allowed. At allocation A^0, i's marginal cost of abatement exceeds j's. Hence, i would be willing to pay j more to abate a unit of emission than j would require in order to profit from trading; there are potential gains from trade. If the market is perfectly competitive, trading will continue until all gains from trade have been exhausted; this point occurs where the marginal cost curves cross, at allocation A^* and market clearing price P^*. A^0 might be thought of as the *ex ante* allocation, and A^* as the *ex post* allocation of TCEEs.

If all trading takes place at price P^*, Country i will buy $A^* - A^0$ entitlements from j,

and pay j the area a+b. At the same time, i will then only have to abate E^0_i - A* units, at a total cost equal to area c. Country j will then have to abate E^0_j - A* units of emission at a total cost equal to area b. Hence, Country j receives a surplus of TCEE revenue over cost equal to area a. Country i pays j the amount a+b and incurs abatement costs equal to area c. Hence, Country i incurs a total cost equal to area a+b+c.

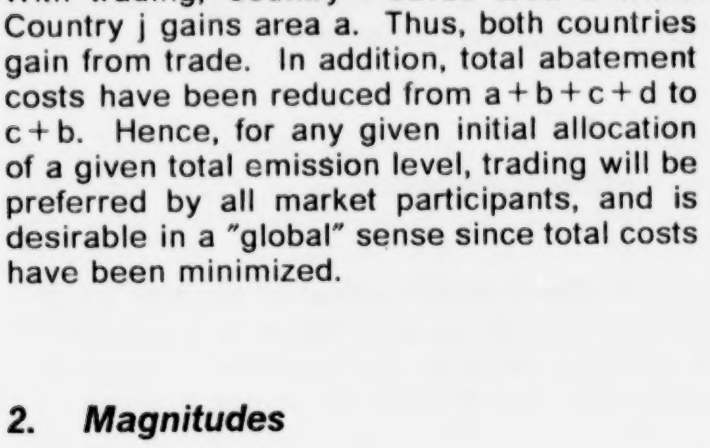
Note that, given the initial allocation, both countries gain from trading. If no trading were to take place, Country i would incur costs equal to a+b+c+d to meet its obligation, while Country j would incur no costs. With trading, Country i saves area d while Country j gains area a. Thus, both countries gain from trade. In addition, total abatement costs have been reduced from a+b+c+d to c+b. Hence, for any given initial allocation of a given total emission level, trading will be preferred by all market participants, and is desirable in a "global" sense since total costs have been minimized.

2. *Magnitudes*

The magnitudes of the gains and losses identified so far depend on (1) the initial allocation A^0, (2) the total quantity of TCEEs, and (3) the nature of the abatement cost curves.

Figure 2

EQUILIBRIUM PRICE AND GAINS FROM TRADE ON THE ASSUMPTION THAT TOTAL QUANTITY OF TCEEs EQUALS SUM OF STATUS QUO EMISSIONS



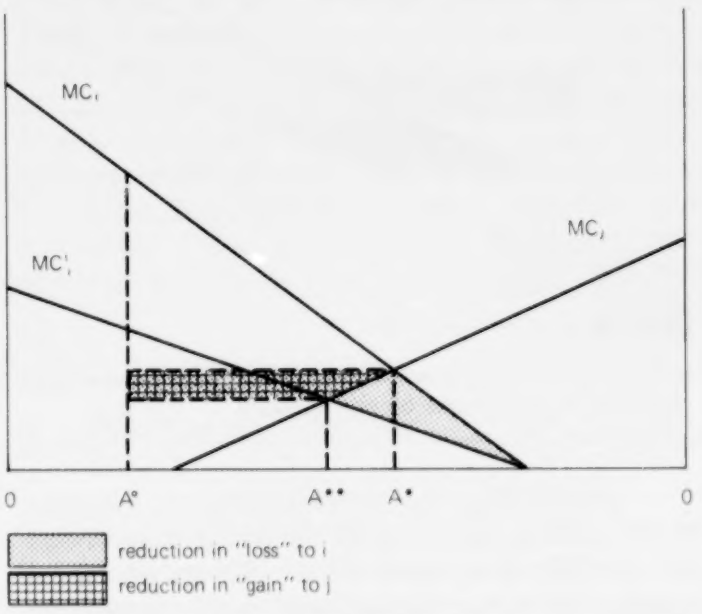
Source: Calculations by the author.

The effect of the initial allocation can be seen by moving the initial allocation A^0 slightly to the right in figure 1. Plainly, areas a and d are reduced. Country i incurs lower costs plus TCEE payments and j has a smaller surplus of revenues over costs.

The effect of changes in the total quantity of TCEEs can be seen as changing the length of the horizontal axis in figure 1. Figure 2 is identical to figure 1 except that the total quantity of TCEEs made available has been increased to exactly equal to the sum of status quo emissions. At the allocation A^0, Country i faces a deficit in TCEEs and Country j a surplus. However, if the market for TCEEs were perfectly competitive, trading would take place at zero price, and no resources would be transferred, the reason being that TCEEs would not be scarce.

Figure 3

EFFECTS OF CHANGES IN SLOPE IN MARGINAL ABATEMENT COST CURVE



Source: Calculations by the author.

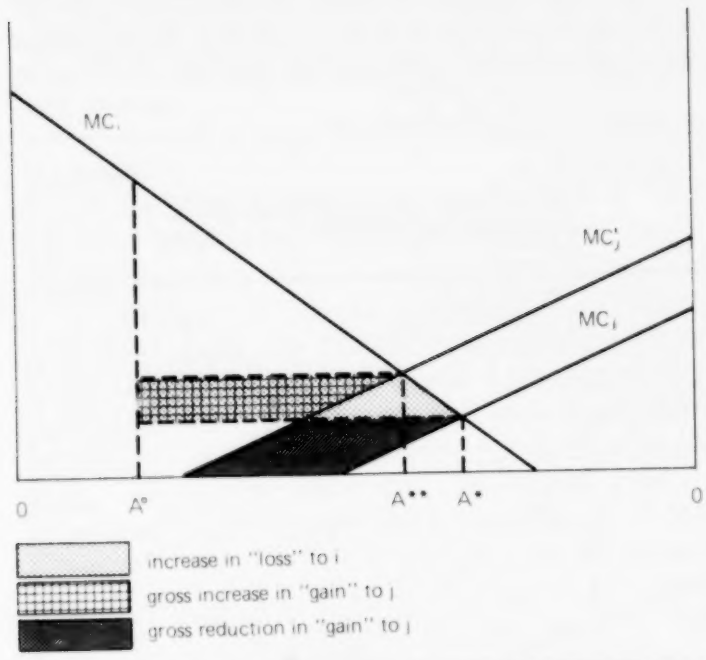
Finally, to see the effect of changes in the nature of the cost curves, suppose i's abatement cost curve were flatter than shown in figure 1. Figure 3 shows the original cost curves, MC_i and MC_j , and i's flatter cost curve MC_i '. It is clear from the figure that Country j now receives a smaller surplus of TCEE revenue over abatement cost, and Country i bears a smaller cost in terms of TCEE purchases plus abatement costs than before. A similar analysis can be carried out for changes in the slope of j's marginal abatement cost curve.

Suppose now that Country j's marginal abatement cost curve were shifted outwards to MC_j ', as in figure 4. Then we see that Country i bears a greater total burden than before. For Country j the difference is more

ambiguous; its surplus is increased as a consequence of the higher price at which TCEEs are traded, but decreased as a consequence both of a reduction in the quantity of TCEEs traded and an increase in its own costs of abatement. Again, a similar analysis can be carried out for shifts in i's marginal abatement cost curve.

Figure 4

EFFECTS OF SHIFTS IN MARGINAL ABATEMENT COST CURVE



Source: Calculations by the author.

One reason for stressing the importance of the nature of the cost curves is that these will be changing over time. As an economy grows, its cost curve will shift outwards. However, changes in technology will also affect the nature of the cost curve, and in the short run we can expect that the marginal abatement cost curves will be steeper than in the long run, all else remaining constant.

3. *Benefits*

Obviously, we can only tell whether a country gains from an agreement in some real sense by calculating benefits as well as costs. Benefits should be calculated as the sum of the damages that will occur as a consequence of climate change plus the costs incurred in adapting to climate change, when the level of adaptation chosen has been such that the marginal cost of adaptation just equals the damage which the incremental measure avoids (see the appendix in Barrett, 1991a).

If a country receives a surplus of TCEEs (and TCEEs are scarce in total), then we know that it receives more in TCEE payments than it pays in abatement costs. Hence, as long as countries receiving a surplus of TCEEs benefit from abatement, their net benefits from participating in the treaty must be positive. If a country is allocated fewer TCEEs than its status quo emission level, then this result cannot be guaranteed.

4. *Interdependence*

It might seem natural to say that an allocation should be acceptable to a country if it receives positive net benefits. However, when deciding whether to accept a given allocation, a country is likely to compare the net benefits it receives if it participates in the treaty with the net benefits it receives if it does not participate, and in the latter case these are likely to be greater than zero.

Let us assume that if one country does not participate in the treaty, no countries do.[5] Then it is not enough for a country's net benefits to be positive from participation, because it is unlikely that countries will continue to emit their status quo levels. If negotiations fail, countries will still have some unilateral incentive to abate their emissions, even if by only a small amount (see Barrett, 1990). Countries will have unilateral incentives to abate their emissions up to the point at which their own marginal cost of abatement equals their own marginal benefit from abatement (this defines the Nash equilibrium in this "game"). At this level, net benefits will be positive, and not zero. Hence, the conditions that must hold for participation to be attractive will have to be even more compelling than the expectation that net benefits through participation will be positive; they must exceed the net benefits if negotiations fail, and these net benefits will in themselves be positive.

5 This is a harsh assumption. However, this paper is focusing on the three top emitting countries. Hence, the assumption amounts to saying that if any one of these parties does not sign the agreement, then none does. Note that the Montreal Protocol will not come into effect until signed by at least 11 countries accounting for at least two thirds of global consumption of the listed substances. Hence, our assumption seems to have been embodied in the Montreal Protocol.

Even this is a minimal requirement. For it may be attractive for countries to form coalitions and break ranks together. If this is the case, then the analysis must compare the net benefits a country receives through the treaty with the net benefits it would receive as part of a coalition. The country will want to join this coalition only if it receives higher net benefits than if it acts unilaterally (see Barrett, 1991d, for an analysis of coalitions).

This chapter defines an allocation as acceptable if each country receives a higher level of net benefits with the given allocation than it would if an agreement were not reached and all countries chose their non-cooperative abatement levels. This approach is more sophisticated than the approach requiring positive net benefits, but less sophisticated than the approach that examines incentives for coalition formation.

C. Analysis

This section combines the allocation rules discussed in section A and the conceptual system presented in section B to provide insights into the acceptability of the various allocation rules to the different negotiating parties.

1. *Background*

Table 2 presents basic background data on the 20 countries with the highest CO_2 emission levels in 1989. Together, these countries account for about 80 per cent of global emissions (both in 1989 and cumulatively).

It must be stressed at the outset that these and other data presented in this paper are used only for illustrative purposes. One of the first challenges facing negotiators will be to agree on a common set of data. It is assumed here that negotiators agree on the data presented here and later in the chapter. However, in actual negotiations, these data may not be accepted in their present form.

It is clear from table 2 that countries differ substantially in their "starting points." Table 3 ranks the top 20 emitting countries according to a number of criteria. Rankings according to 1989 emissions and cumulative emissions do not vary much. However, there is a substantial difference in the rankings between emissions per capita and emissions per unit of GNP. In terms of emissions per capita, the OECD countries tend to rank high and the developing countries low. In terms of emissions per unit of GNP, the OECD countries tend to rank low and the developing countries high. In both cases, the former Soviet Union and the Eastern European countries tend to lie between these extremes. Table 4 indicates that growth rates in emissions also vary substantially. In general, the OECD have low growth rates, the former Soviet Union and the Eastern European countries medium growth rates, and the poorer countries high growth rates. The fact that countries differ substantially indicates that agreement will not be easy to reach.

2. *Method of analysis*

It is assumed that each country knows the costs and benefits that it will receive under any treaty proposal. This is an important assumption, as much uncertainty surrounds estimates of both costs and benefits. Research on the economics of climate change is improving our knowledge about these estimates, but it seems unlikely that the uncertainties will be reduced very substantially unless the uncertainties about the science of climate change are themselves reduced.

In most instances, it will also be assumed that countries care only about their own net benefits, and not about the net benefits received by other countries. This may be an extreme assumption, but if one can show that self-interest can lead to agreement, then clearly concern for the well-being of other countries will only reinforce this conclusion.

Every country is further assumed to know the net benefits that it would receive if negotiations failed. It follows from the conceptual discussion presented earlier that a

Table 2

CO_2 EMISSIONS DATA FOR THE 20 COUNTRIES WITH THE HIGHEST EMISSIONS IN 1989

	1989 emissions	*1950-1989 cumulative emissions*	*1989 emissions per capita*	*1987 GNP per capita*	*1987 emissions per GNP*
	Million tons carbon		*Tons*	*Dollars*	*Tons per $10,000*
United States	1,328.3	41,396.1	5.37	18,529	2.8
Soviet Union	1,038.2	25,255.1	3.62	8,375	4.3
China	651.9	10,328.1	0.59	294	19.0
Japan	284.0	6,438.1	2.31	15,764	1.3
India	177.9	2,690.0	0.21	311	6.1
FRG	175.1	6,881.3	2.86	14,399	2.1
United Kingdom	155.1	6410.6	2.70	10,419	2.6
Canada	124.3	3,301.3	4.73	15,160	2.9
Poland	120.3	3,294.1	3.15	1,926	17.6
Italy	106.4	2,601.0	1.86	10,355	1.7
France	97.5	3,942.7	1.74	12,789	1.4
GDR	88.1	3,036.8	5.40	11,300	4.9
Mexico	87.3	1,550.3	1.01	1,825	5.4
South Africa	76.0	1,748.8	2.20	1,870	12.5
Australia	70.3	1,562.7	4.22	11,103	3.6
Czechoslovakia	61.8	2,154.4	3.95	9,280	4.5
Republic of Korea	60.3	749.6	1.42	2,689	4.4
Romania	57.9	1,301.5	2.50	6,030	4.2
Brazil	56.5	1,125.2	0.38	2,021	1.9
Spain	55.5	1,266.8	1.42	5,972	2.1
Global	5,967.0	152,627.0	1.15	3,012	3.8

Source: Emissions data provided to the author by the Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory. GNP per capita data are from World Resources Institute (1990), table 15.1; Global GNP per capita has been obtained by dividing total GNP in 1987 from table 15.1 by population in 1990 from table 16.1.

Note: The data for the FRG and GDR relate to the period before the reunification of Germany.

treaty proposal can be said to be ***acceptable*** to a country if that country's net benefits are at least as great under the proposal as they would be if negotiations failed. As noted earlier, this is a fairly weak condition; it might be possible for coalitions of countries to do even better by breaking off on their own.

To simplify the analysis, I shall consider negotiations involving only the United States, the former Soviet Union and China. This restriction can be justified by the fact that these three countries are the largest emitters of CO_2, and that each country broadly represents the three main country groups: the OECD countries, the former Soviet Union and Eastern European countries, and the developing countries. Previous analysis by Barrett (1991c) suggests that the United States could reach agreement with the other OECD countries, as differences within this group of countries are not great. It is likely that a similar result would hold good for negotiations involving the former Soviet Union and other Eastern European countries, and China and the other developing countries, although this has yet to be demonstrated.

To give the analysis some empirical content, information on benefits and costs is taken from Nordhaus's (1991) well-known economic analysis of global climate change. Nordhaus calculates a marginal abatement

Table 3

RANKING OF TOP 20 CO_2 EMITTERS IN 1989 ACCORDING TO ALTERNATIVE CRITERIA

1989 emissions	*Cumulative emissions*	*1989 emissions per capita*	*1987 emissions per unit of GNP*
United States	United States	GDR	China
Soviet Union	Soviet Union	United States	Poland
China	China	Canada	South Africa
Japan	FRG	Australia	India
India	Japan	Czechoslovakia	Mexico
FRG	United Kingdom	Soviet Union	GDR
United Kingdom	France	Poland	Czechoslovakia
Canada	Canada	FRG	Republic of Korea
Poland	Poland	United Kingdom	Soviet Union
Italy	GDR	Romania	Romania
France	India	Japan	Australia
GDR	Italy	South Africa	Canada
Mexico	Czechoslovakia	Italy	United States
South Africa	South Africa	France	United Kingdom
Australia	Australia	Republic of Korea	Spain
Czechoslovakia	Mexico	Spain	FRG
Republic of Korea	Romania	Mexico	Brazil
Romania	Spain	China	Italy
Brazil	Brazil	Brazil	France
Spain	Republic of Korea	India	Japan

Source: The rankings are obtained directly from table 2.
Note: As for table 2.

cost function using United States data that take the form (for a Country i):

$$MC_i(X_i; \alpha_i) = 1n(1 - X_i)/\alpha_i \qquad (1)$$

where MC_i is Country i's marginal abatement cost, X_i is percentage abatement by Country i, and α_i is a parameter. Nordhaus's cost curve suggests that $\alpha = -0.00357$ for the United States, or that United States CO_2 emissions could be reduced 30 per cent at a marginal cost of $100 per ton of carbon. Analysis by Barrett (1991f) of engineering data for 10 European countries found that estimates for the parameter α varied from -0.0002 to -0.0167. Four countries had parameter values that exceeded the Nordhaus estimate, while six had smaller estimates. Little is known about the abatement cost functions for the former Soviet Union and China. This chapter assumes that all three countries have the same marginal abatement cost function. While this assumption is bound to be wrong, it seems difficult to argue for higher or lower parameter values for the former Soviet Union and China. A discussion of the possible sensitivity of the results to this assumption is presented at the end of this section.

While the marginal abatement cost function is assumed to be identical for the three countries, the ***total*** abatement cost functions will not be identical. Marginal abatement costs are assumed to depend on percentage abatement, but the base levels of emissions vary among the three countries. The total abatement cost function corresponding to equation (1) can be shown to equal (see Barrett, 1991f):

$$TC_i(X_i, E_i; \alpha_i) = -E_i[(1 - X_i)1n(1 - X_i) + X_i]/\alpha_i \qquad (2)$$

where TC_i is Country i's total abatement cost, and E_i is Country i's base year level of emissions. Hence, even assuming that α_i are identical for all i, total costs will vary. If all countries undertake the same percentage

Table 4

CARBON DIOXIDE EMISSION GROWTH RATES

(Per cent)

	1950-1989	*1973-1989*
United States	1.66	0.26
Soviet Union	4.40	2.20
China	8.72	5.61
Japan	5.91	0.78
India	5.82	6.68
FRG	1.57	-1.25
United Kingdom	0.30	-0.79
Canada	2.76	1.25
Poland	3.48	1.74
Italy	5.73	0.91
France	1.44	-2.06
GDR	1.81	0.96
Mexico	6.03	5.66
South Africa	3.90	2.99
Australia	3.96	2.96
Czechoslovakia	3.51	2.19
Republic of Korea	11.82	7.19
Romania	6.13	2.36
Brazil	6.02	2.73
Spain	4.64	2.05
Global	3.31	1.56

Source: Calculated from data provided by the Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory. Estimates are based on emissions at the end points (1950 and 1989, and 1973 and 1989), and are compound growth rates.

Note: As for table 2.

abatement, total costs will be greater for the United States than for China and the former Soviet Union because the United States has a higher base level of emissions.

Nordhaus also estimates the marginal benefit from abatement. His estimates take into account the fact that a unit of emission today will cause damage over a period of time. He calculates a base case (or middle case) marginal damage of $7.33/t C, which is consistent with total damage equal to 1 per cent of global output. He also calculates a high case marginal damage of $66/t C, which corresponds to a 2 per cent reduction in global output. These estimates are controversial, but they are grounded in an easily understood analysis that is also widely known.

Nordhaus takes the marginal damage associated with current abatement to be constant. He calculates damages based on estimates for the United States, and then extrapolates to arrive at the global figures. Since Nordhaus's estimates are based on GNP, it seems natural to assume that the marginal damage suffered by any Country i will equal global marginal damage multiplied by i's share of global GNP:

$$MB_i = MB^* G_i/G \qquad (3)$$

where MB_i is Country i's marginal benefit from abatement, MB^* is the global marginal benefit, G is global output, and G_i is i's level of output. Since the United States has higher output than either the former Soviet Union or China, this method of calculation implies that

it would have a higher marginal benefit from abatement than either of the other two countries. This chapter employs the assumption of constant marginal benefit, but includes both the base and high case estimates. The sensitivity of the results to changes in this assumption is discussed at the end of this section.

Since marginal benefits are assumed to be constant, i's total benefits (TB_i) will equal:

$$TB_i = MB_i^{*}\Sigma_i X_i E_i \qquad (4)$$

If trading in TCEEs is perfect, trade will take place until the marginal abatement costs are equalized over all countries. Assuming α_i are identical for all i, the equilibrium price of TCEEs, P^*, is easily calculated as:

$$P^* = 1n[\Sigma_i(1 - X_i)E_i/E]/\alpha \qquad (5)$$

where $E = \Sigma_i E_i$.

The total transfers going to Country i as a consequence of trading can then be calculated by multiplying the difference between the TCEEs allocated *ex ante* and the TCEEs distributed *ex post* by the equilibrium price P^*.

3. *Dynamic vs. static analysis*

The analysis is static in so far as it does not calculate emission rates and abatement levels over time. However, as table 4 indicates, the situation itself is not static; emissions are growing, especially in the developing countries.

The static analysis should not be taken to imply that emissions are to be reduced from their current levels and thereafter remain constant. Rather, it can be assumed that countries agree on a baseline trend in emissions (the so-called "business-as-usual" scenario), and are undertaking abatement from this trend. If the abatement cost functions were stable (i.e. did not change as a function of time), and the marginal abatement benfits were constant, then countries would want to undertake the same percentage abatement over time for the cases considered. For example, where this chapter indicates that a country would want to abate its emissions 1 per cent in the non-cooperative outcome, these assumptions would indicate that the country would want to reduce its emissions 1 per cent every year relative to the baseline trend. If the trend were increasing, actual abatement would increase, but so would emissions after abatement. Given the current high rate of emissions in developing countries, and the need for these economies to grow, it seems likely that an agreement reducing fossil fuel CO_2 emissions will allow emissions in these countries to rise, at least for the foreseeable future.

The assumptions that marginal abatement costs are stable and marginal abatement benefits constant are, however, unrealistic. For example, in the very long run, marginal abatement costs are likely to fall as "backstop" technologies are developed (see Manne and Richels, 1990). Marginal abatement benefits will also change, partly because GNP will be changing as will atmospheric concentrations of greenhouse gases, and also partly because of technological progress. R and D in agriculture, for example, may reduce the damage associated with climate change.

Any effective agreement must be capable of responding to these anticipated developments as well as to an evolved understanding of the science of climate change. One potential problem is that an agreement may be initially acceptable to a certain number of countries, but cease to be acceptable over time as the nature of costs and benefits changes.

A consideration of the dynamics also complicates the nature of the negotiation "game". Actions taken in the current period may well affect other countries' actions in future periods, and countries may want to take those reactions into account in the former. In addition, greenhouse gases accumulate in the atmosphere, and so actions taken in the current period will affect future concentrations. These considerations are ignored in the present analysis, but they can be very important.[6]

4. *Background analysis*

The data for the analysis are contained in table 5. Note that the values for the United States and China are usually far apart, with values for the former Soviet Union lying somewhere in between. The exception is emissions per land area, which are lower for the latter than for either of the other two countries.

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6 For discussions on the dynamic aspects of environmental policy, see Mäler (1991) and Hoel (1992).

Table 5

DATA FOR ANALYSIS

	United States	*Soviet Union*	*China*	*Total*	*Global*
1989 emissions [a]	1,328.3	1,038.2	651.4	3,017.9	5,967.0
Cumulative emissions [a]	41,396.1	25,255.1	10,328.1	76,979.3	152,627.0
1989 emissions per capita [b]	5.37	3.62	0.59	2.73	1.15
Cumulative emissions per capita	167.3	88.1	9.4	47.0	29.4
1987 GNP [c]	4,516.7	2,356.7	313.7	7,187.1	15,940.1
1987 emissions per GNP [d]	2.78	4.34	18.93	3.99	3.55
Land area [e]	916,660	2,227,200	932,641	4,076,501	13,076,536
1989 emissions/land area [f]	1.45	0.47	0.70	0.74	0.46
Population [g]	247.4	286.8	1,104.1	1,638.3	5,188.7

Source: Emissions data from table 2. GNP and land area from World Resources Institute (1990), tables 15.1 and 17.1.

a Million tons of carbon.
b Tons of carbon.
c Millions of dollars.
d Tons of carbon per $10,000 GNP.
e Thousands of hectares.
f Tons per hectare.
g Billions; obtained by dividing emissions by emissions per capita.

As explained in section B, if negotiations fail, it is reasonable to assume that countries will undertake some level of abatement on their own. While any one country will receive only a small share of the benefit associated with its own abatement, it does receive some benefit from it, and hence will find it in its own interest to bear some abatement costs. It is assumed here that countries will abate their emissions up to the point where their marginal cost of abatement equals their marginal benefit from abatement. These levels are shown in table 6 - Base Case analysis - under the non-cooperative outcome. The United States undertakes more abatement than the other countries in percentage terms because, under our assumptions, its marginal benefit from abatement is higher. It must be emphasized again that these estimates should be understood to correspond to abatement in a given year, and not to a permanent stabilization in emissions.

If the three countries were able to cooperate fully, but other countries did not cooperate, then each of the three countries would choose an abatement level at which their marginal cost of abatement equalled the marginal benefit from abatement for all three. This outcome is shown in table 6 as the "limited cooperative outcome." Note that, while total net benefits are higher for the United States and former Soviet Union compared with the non-cooperative outcome, China does worse; in fact, it receives negative net benefits. Clearly, China would have to receive side payments for this outcome to be acceptable to it.

Finally, if all countries cooperate fully, then each will choose a level of abatement at which its marginal cost of abatement equals the global marginal benefit. Total net benefits for the United States and former Soviet Union are higher under this "global cooperative outcome," but China still earns negative net benefits.

Table 7 carries out the same analysis for the High Case under which global marginal abatement benefits are $66/t C. As might be expected, greater abatement is optimal under all three scenarios when benefits are expected to be higher.

These scenarios establish the benchmarks for the analysis. For an agreement to be acceptable to any party, it must give that party a net benefit at least as great as that associated with the non-cooperative outcome. The maximum total net benefit to the three parties is given by the limited cooperative

Table 6

BASE CASE ANALYSIS [a] - NON-COOPERATIVE, LIMITED COOPERATIVE AND GLOBAL COOPERATIVE OUTCOMES

	United States	*Soviet Union*	*China*	*Total*	*Global*
Non-cooperative outcome [b]					
Percentage abatement	0.74	0.39	0.05	0.47	0.24
Net benefits (millions of dollars)	19.2	13.2	2.0	34.4	91.4
Limited cooperative outcome [b]					
Percentage abatement	1.17	1.17	1.17	1.17	0.59
Net benefits (millions of dollars)	47.8	18.3	-7.5	58.6	201.1
Global cooperative outcome					
Percentage abatement	2.58	2.58	2.58	2.58	2.58
Net benefits (millions of dollars)	194.9	69.2	-39.2	224.9	567.3

Source: Calculations by the author.

a Assuming a global marginal benefit from abatement of $7.33 per ton C, marginal benefits proportional to GNP, and a marginal abatement cost parameter $\alpha = -.00357$.

b Assuming ***no*** abatement undertaken by countries other than the United States, the former Soviet Union and China. The actual non-cooperative outcome ***will*** involve some abatement by other countries, so the net benefit figures shown are biased downwards.

outcome. The fact that there is a difference between these two outcomes indicates that all parties can gain by reaching agreement.

Tables 8 and 9 summarize the results of the analysis of trading in TCEEs under the allocation schemes listed in section A. These results are discussed below.

5. *Uniform percentage abatement*

Table 8 shows the uniform percentage abatement levels that would be preferred by each of the three parties. These "preferred" levels are found by allowing each country to choose a uniform percentage abatement level that maximizes its own net benefits. The United States would prefer a uniform abatement level of 1.67 per cent, the former Soviet Union of 1.12 per cent, and China of 0.24 per cent. These different preferences reflect the differences in marginal benefits for the three countries. As is to be expected, the equilibrium price of TCEEs is higher when more abatement is undertaken. However, no surpluses are earned by any country because, by assumption, each country has the same marginal abatement cost schedule. Since all countries are allocated TCEEs to reduce their emissions by the same percentage, and marginal costs are the same for the same percentage abatement, no trading takes place.

Comparing tables 6 and 8, one finds that this allocation rule would be acceptable to the United States and former Soviet Union; they can each earn higher net benefits with this rule than they would if negotiations failed and they earned their "non-cooperative" net benefits. China, however, does worse, even when it chooses the uniform percentage abatement level that maximizes its net benefits. The reason for this is that, if negotiations fail, the United States and former Soviet Union have an incentive to abate even more than this level.

Table 9 shows the same analysis for the High Case. The preferred abatement levels are higher because marginal benefits are higher, and the equilibrium price of TCEEs is also higher because percentage abatement is higher. As with the Base Case, no trading takes place because under our assumptions this allocation rule provides no gains to trade.

Table 7

HIGH CASE ANALYSIS [a] - NON-COOPERATIVE, LIMITED COOPERATIVE AND GLOBAL COOPERATIVE OUTCOMES

	United States	*Soviet Union*	*China*	*Total*	*Global*
Non-cooperative outcome [b]					
Percentage abatement	6.46	3.42	0.46	4.12	2.08
Net benefits (millions of dollars)	1,532.2	1,040.9	159.6	2,732.7	7,239.1
Limited cooperative outcome [b]					
Percentage abatement	10.08	10.08	10.08	10.08	5.10
Net benefits (millions of dollars)	3,731.7	1,438.7	-564.5	4,605.9	15,629.5
Global cooperative outcome					
Percentage abatement	20.99	20.99	20.99	20.99	20.99
Net benefits (millions of dollars)	14.584.6	5,312.9	-2,708.5	17,189.0	42,957.1

Source: Calculations by the author.

a Assuming a global marginal benefit from abatement of $66 per ton C, marginal benefits proportional to GNP, and a marginal abatement cost parameter α = -.00357.

b Assuming ***no*** abatement undertaken by countries other than the United States, the former Soviet Union and China. The actual non-cooperative outcome ***will*** involve some abatement by other countries, so the net benefit figures shown are biased downwards.

In comparing tables 7 and 9, it will again be found that uniform percentage abatement is acceptable to the United States and former Soviet Union, but not to China. China does better if negotiations fail and countries choose their non-cooperative abatement levels.

6. *Uniform per capita entitlements*

Table 8 shows that the United States and former Soviet Union cannot find any per capita entitlement of TCEEs that yields positive net benefits for them. Hence, they would not agree to negotiate using this instrument. China, however, would prefer TCEEs to be allocated on the basis of 0.9 tons per capita; in this case, China would receive a huge volume of transfers from the United States and former Soviet Union. However, net benefits for all three countries are substantially negative under this allocation scheme.

The same general results hold good for the High Case. However, net benefits are now higher for all countries (although still negative in total) under China's preferred choice.

The reason for these results is rather obvious. Both the United States and former Soviet Union have much higher emissions per capita than the average for all three countries. Hence, even if emissions are reduced only slightly, this allocation scheme will result in huge transfers to China, with little environmental benefit to the other two countries. Even a high marginal benefit cannot overcome the wide gap in the starting-point values for emissions per capita that exists between the United States/Soviet Union and China.

7. *Uniform per GNP entitlements*

If TCEEs are allocated on the basis of GNP, then this will be acceptable to the United States under the Base Case, but not to the other countries. The situation is analogous to the per capita allocation mechanism. Both the former Soviet Union and China have higher emissions per unit of GNP than the average for all three countries. Hence, any

Table 8

BASE CASE TCEE ANALYSIS

	United States	*Soviet Union*	*China*	*Total*
Uniform percentage abatement				
Preferred choice (per cent)	1.67	1.12	0.24	-
Equilibrium price	$4.72	$3.15	$0.67	-
Net benefits @ 1.67 per cent	52.5	13.8	-18.3	48.0
Net benefits @ 1.12 per cent	46.7	18.3	-6.6	58.5
Net benefits @ 0.24 per cent	13.9	7.0	0.5	21.4
Uniform per capita entitlements				
Preferred choice	-	-	0.93	-
Percentage abatement	-	-	49.36	-
Equilibrium price	-	-	$190.61	-
Net benefits @ 0.93	-136,584.1	-90,946.0	106,453.5	-121,076.5
Transfers @ 0.93	-84,220.5	-49,214.6	133,435.1	0
Uniform per GNP entitlements				
Preferred choice	3.08	-	-	-
Percentage abatement	26.76	-	-	-
Equilibrium price	$87.24	-	-	-
Net benefits @ 3.08	23,285.1	-13,720.8	-40,295.8	-30,731.7
Transfers @ 3.08	36,308.7	-3,105.8	-33,202.9	0
Uniform per land area entitlements				
Preferred choice	-	0.51	0.70	-
Percentage abatement	-	31.40	5.70	-
Equilibrium price	-	$105.72	$16.47	-
Net benefits @ 0.51	-65,810.0	29,119.8	-7,178.3	-43,868.5
Transfers @ 0.51	-47,092.1	44,261.7	2,830.5	0
Net benefits @ 0.70	-10,351.5	9,187.5	328.0	-836.0
Transfers @ 0.70	-10,090.8	9,484.3	606.5	0
Inverse per capita emission rule				
Preferred choice (percentage abatement)	-	-	51.52	-
Equilibrium price	-	-	$202.78	-
Net benefits @ 51.52 per cent	-161,743.6	-109,557.2	137,661.1	-133,639.8
Transfers @ 51.52 per cent	-103,890.9	-63,500.6	167,391.5	0
Inverse cumulative emission rule				
Preferred choice (percentage abatement)	-	-	47.33	-
Equilibrium price	-	-	$179.58	-
Net benefits @ 47.33 per cent	-130,315.2	-64,728.1	85,120.1	-109,923.2
Transfers @ 47.33 per cent	-82,822.5	-26,836.9	109,659.4	0
Weighted average rule - Δ = 0.50				
Preferred choice (percentage abatement)	-	-	40.31	-
Equilibrium price	-	-	$144.53	-
Net benefits @ 40.31 per cent	-70,494.2	-48,330.5	42,459.8	-76,364.9
Transfers @ 40.31 per cent	-37,640.0	-21,995.1	59,635.1	0

Table 8 (concluded)

BASE CASE TCEE ANALYSIS

	United States	*Soviet Union*	*China*	*Total*
Weighted average rule - Δ = 0.02				
Preferred choice (percentage abatement)	0.38	0.14	4.20	-
Equilibrium price	$1.05	$0.40	$12.05	-
Net benefits @ 0.38 per cent	2.6	-0.5	29.3	31.5
Transfers @ 0.38 per cent	-18.3	-10.7	29.0	0
Net benefits @ 0.14 per cent	1.6	0.3	11.6	13.5
Transfers @ 0.14 per cent	-7.0	-4.1	11.1	0
Net benefits @ 4.20 per cent	-271.9	-241.3	173.4	-339.8
Transfers @ 4.20 per cent	-201.4	-117.7	319.1	0
Two-tier allocation - Base Case				
Obligation (percentage abatement)	1.00	1.00	0.00	0.78
Equilibrium price	$2.20	$2.20	$2.20	$2.20
Net benefits	31.33	11.72	9.08	52.13
Transfers	-6.34	-4.95	11.29	0
"Kantian" allocation rule				
Percentage abatement	1.67	1.12	0.24	1.12
Equilibrium price	$3.30	$3.30	$3.30	$3.30
Net benefits	26.0	20.1	12.6	58.6
Transfers	-21.8	1.8	20.1	0

Source: Calculations by the author.

Note: A dash (-) indicates that the preferred choice was not feasible.

agreement that uses this instrument and reduces emissions in total must result in substantial transfers from these countries to the United States. The only way these countries can find this instrument acceptable is if they receive high environmental benefits. Under the High Case, the former Soviet Union can find an allocation that provides it with positive net benefits - the reason being that its level of emissions per unit of GNP is fairly close to the average - but even for the High Case this instrument is not acceptable to it.

8. *Uniform per land area entitlements*

If TCEEs are allocated on the basis of land area, then agreement among all three parties still cannot be reached. Both the former Soviet Union and China would find this formula acceptable. However, the United States would only be made worse off under it. The reason is again indicated by table 5. As the United States has a level of emission per land area that is much higher than the average, any allocation on the basis of land area must result in huge transfers from the United States to the other two countries.

9. *Inverse per capita emission rule*

If TCEEs are allocated in inverse proportion to per capita emissions, then the outcome is similar (but not identical) to the case in which emissions are allocated on the basis of population. China would find this instrument acceptable, but not the United States or former Soviet Union. The emissions per capita of the two latter are much higher than the average for all three countries, so under this rule they would be required to make substantial transfers to China.

Table 9

HIGH CASE TCEE ANALYSIS

	United States	*Soviet Union*	*China*	*Total*
Uniform percentage abatement				
Preferred choice	14.07	9.60	2.10	-
Equilibrium price	$42.49	$28.36	$6.02	-
Net benefits @ 14.07 per cent	4,072.1	1,118.8	-1,346.8	3,844.1
Net benefits @ 9.60 per cent	3,651.7	1,441.9	-497.2	4,596.4
Net benefits @ 2.10 per cent	1,114.9	559.7	41.8	1,716.4
Uniform per capita entitlements				
Preferred choice	-	-	0.93	-
Percentage abatement	-	-	49.67	-
Equilibrium price	-	-	$192.33	-
Net benefits @ 0.93	-112,668.2	-78,686.2	108,179.0	-83,175.5
Transfers @ 0.93	-84,459.3	-49,354.1	133,813.5	0
Uniform per GNP entitlements				
Preferred choice	2.80	3.97	-	-
Percentage abatement	33.40	5.60	-	-
Equilibrium price	$113.69	$16.00	-	-
Net benefits @ 2.80	38,392.7	-12,218.6	-49,583.8	-23,409.7
Transfers @ 2.80	43,054.6	-3,682.8	-39,371.8	0
Net benefits @ 3.97	11,136.1	443.7	-7,921.5	3,658.2
Transfers @ 3.97	8,587.2	-734.5	-7,852.6	0
Uniform per land area entitlements				
Preferred choice	-	0.48	0.69	-
Percentage abatement	-	35.22	7.39	-
Equilibrium price	-	$121.60	$21.52	-
Net benefits @ 0.48	-57,692.7	37,848.6	-8,484.4	-28,328.5
Transfers @ 0.48	-51,179.5	48,103.4	3,076.2	0
Net benefits @ 0.69	-9,816.7	13,530.9	556.4	4,270.6
Transfers @ 0.69	-12,946.9	12,168.7	778.2	0
Inverse per capita emission rule				
Preferred choice (percentage abatement)	-	-	51.77	-
Equilibrium price	-	-	$204.26	-
Net benefits @ 51.77 per cent	-136,651.1	-96,662.6	139,460.7	-93,853.1
Transfers @ 51.77 per cent	-104,097.7	-63,627.0	167,724.7	0
Inverse cumulative emission rule				
Preferred choice (percentage abatement)	-	-	47.69	-
Equilibrium price	-	-	$181.51	-
Net benefits @ 47.69 per cent	-107,545.3	-53,009.9	86,775.6	-73,779.5
Transfers @ 47.69 per cent	-83,136.9	-26,938.8	110,075.7	0
Weighted average rule - $\Delta = 0.50$				
Preferred choice (percentage abatement)	-	-	40.86	-
Equilibrium price	-	-	$147.13	-
Net benefits @ 40.86 per cent	-51,349.0	-38,638.2	43,874.0	-46,113.3
Transfers @ 40.86 per cent	-37,962.5	-22,183.6	60,146.1	0

Table 9 (concluded)

HIGH CASE TCEE ANALYSIS

	United States	*Soviet Union*	*China*	*Total*
Weighted average rule - $\Delta = 0.03$				
Preferred choice (percentage abatement)	12.60	8.41	7.69	-
Equilibrium price	$37.71	$24.60	$22.42	-
Net benefits @ 12.60 per cent	3,162.2	794.6	348.3	4,305.1
Transfers @ 12.60 per cent	-862.6	-504.2	1,367.1	0
Net benefits @ 8.41 per cent	2,801.8	1,073.3	600.3	4,475.5
Transfers @ 8.41 per cent	-589.8	-344.7	934.5	0
Net benefits @ 7.69 per cent	2,669.7	1,065.4	605.6	4,340.7
Transfers @ 7.69 per cent	-541.8	-316.6	858.5	0
Two-tier allocation - High Case				
Obligation (percentage abatement)	8.00	8.00	0.00	6.27
Equilibrium price	$18.15	$18.15	$18.15	$18.15
Net benefits	2,376.1	937.3	620.9	3,934.3
Transfers	-416.3	-325.4	741.8	0
Obligation (percentage abatement)	13.00	13.00	0.00	10.19
Equilibrium price	$30.12	$30.12	$30.12	$30.12
Net benefits	2,628.1	559.3	1,417.9	4,605.3
Transfers	-1,122.7	-877.5	2,000.2	0
"Kantian" allocation rule				
Percentage abatement	14.07	9.60	2.10	9.97
Equilibrium price	$29.41	$29.41	$29.41	$29.41
Net benefits	2,109.0	1,542.5	953.7	4,605.3
Transfers	-1,603.2	102.4	1,500.8	0

Source: Calculations by the author.
Note: A dash (-) indicates that the preferred choice was not feasible.

10. Inverse cumulative emissions rule

If TCEEs are allocated to parties on the basis of their cumulative emissions, with more TCEEs being allocated to countries with lower cumulative emissions, then agreement will once again prove elusive. China's cumulative emissions are four times lower than those of the United States and 2.5 times lower than those of the former Soviet Union. The allocation therefore results in substantial transfers from these countries to China, and even high environmental damages cannot make the instrument attractive to these two countries.

11. Weighted average rule

Recognizing that the above rules are likely to fail because they ***emphasize*** the differences that exist between the parties, Grubb and Sebenius proposed a ***compromise*** rule, whereby entitlements are allocated according to a weighted average of emissions per capita and uniform percentage reductions. Using a weight of $\Delta = 0.5$, tables 8 and 9 show that even this compromise rule will not prove acceptable to the United States and former Soviet Union. To understand this result, note that uniform percentage abatement is acceptable to these two countries and "almost" acceptable to China. In fact, of all the rules studied thus far, this one comes closest to reaching agreement, and is the only one to yield positive total net benefits when "preferred" levels are chosen. The per capita rule polarizes the parties to a far greater extent. Hence, while a weight of 0.5 might appeal to intuition as a reasonable compromise, it fails to win agreement.

It turns out that agreement can only appear attractive if the weight Δ attached to the per capita component is very small. However, even this tiny weight cannot make the

rule acceptable to the United States and former Soviet Union under the Base Case. The situation is different under the High Case. Using the weight $\Delta = 0.03$ and a total emission reduction of 8.41 per cent does make all three parties better off compared to the non-cooperative outcome. What is more, the outcome using this rule also comes close to the limited cooperative outcome. Hence, this rule does hold some practical attraction even if the rule, and especially a weight like 0.03, does not appear to be an obvious focal point.

12. *Two-tier allocation rule*

Another practical compromise was suggested by Barrett (1991c). This rule involves reaching agreement using two (or more) different instruments - perhaps a uniform percentage abatement level for one group of countries and a uniform per capita rule for another. The inspiration for this rule came from the amended Montreal Protocol. This agreement requires uniform percentage abatement by industrialized countries (100 per cent abatement phased in over a number of years), but allows developing countries to increase their use of CFCs up to a per capita limit of 0.3 kg per capita (in 1984 China consumed 0.02 kg per capita, see UNEP, 1989, table 2.5) for a period of 10 years. Thereafter, these countries must also phase out their use of CFCs.

It is assumed here that the United States and former Soviet Union are treated as industrial countries, and must agree on a uniform percentage abatement level. China is treated as a developing country, and is not required to undertake any abatement. As shown in table 8, this rule performs well in so far as total net benefits come close to the limited cooperative outcome. However, the mechanism will not prove acceptable to the former. The same is true for the High Case. If China is not required to undertake any abatement, and the other two countries must undertake uniform percentage abatement, then the mechanism is not acceptable to the former Soviet Union. The best the former Soviet Union can do is with 8 per cent abatement, but at this level it earns a smaller net benefit than in the non-cooperative case. Total net benefits under this rule are maximized if the United States and former Soviet Union allocate TCEEs on the basis of 13 per cent uniform abatement, whereupon total net benefits are almost exactly equal to the limited cooperative outcome. However, the former Soviet Union will not find this agreement acceptable.

Other simulations have been tried for the case where the former Soviet Union and China are grouped together, but the results are even less successful. The basic problem is that the former Soviet Union lies between the extremes of the United States and China. This sometimes works in its favour when a ***uniform*** obligation is imposed on all three countries. For example, it can find uniform per land area entitlements acceptable when the United States cannot, and can accept uniform percentage abatement when China cannot. However, the two-tier mechanism favours the countries at the extremes - the United States and China - not the country in the middle. The weighted average rule scores better for this reason.

However, if the number of tiers is increased to three, this may no longer be the case; the multi-tier rule may prove more acceptable. Indeed, intuition suggests that this rule would perform well, because it would not polarize negotiations or reach a compromise by favouring the "average" country at the expense of the extremes. This is confirmed below, but for a rule that has a different motivation. It must be mentioned that, while the multi-tier rule may prove better at winning broad agreement, increasing the number of tiers will complicate negotiations.[7]

13. *Ethical principles*

The analysis thus far has considered ethical principles only in so far as such principles suggest uniform allocation mechanisms. We have seen that the implications of using such principles result in outcomes that are arguably unfair.

It is conceivable, however, that countries will not negotiate solely on the basis of self-interest, but on that of "higher" principles

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[7] The European Community Large Combustion Plants Directive is an example in which several tiers were employed in setting obligations. However, this directive took a number of years to negotiate, and negotiations involved only 12 countries that already had formal and daily working relationships.

- the morality of cooperation. Countries might pursue self-interest subject to moral constraints.[8] While bringing moral considerations into the analysis seems reasonable, the analytics of the morality of cooperation are not as straightforward as the analytics of self-interest.

If we take the extreme case in which all countries morally commit themselves to choose abatement levels at which their own marginal costs of abatement equal the global marginal benefit, then the problem of having to reach a cooperative outcome is assumed away. Hence, this case is of interest as a reference point in that it provides the goal towards which negotiations should head, but is of little analytical interest.

Another problem with this moral commitment is that while it guarantees that ***global*** net benefits are maximized, it does not guarantee that the ***distribution*** of net benefits is fair. Tables 6 and 7 indicate that China would receive lower (in fact, negative) net benefits under the global cooperative or moral commitment outcome than under the non-cooperative outcome. To yield an outcome that maximizes global net benefits and results in a fair distribution would require side payments.[9]

It might seem reasonable to consider an intermediate possibility. Suppose that the United States commits itself to undertake the globally optimal abatement level if negotiations fail, whatever the other countries do, but that the former Soviet Union and China continue to equate their marginal costs to their national marginal benefits in the non-cooperative outcome. This assumption is admittedly *ad hoc*, but it might be defended on the grounds that the United States can afford to take this moral position, while the other two countries cannot.

Table 10 shows that United States net benefits in the non-cooperative outcome are now negative, while every other country's net benefits are greater than in the case in which the United States chose its non-cooperative abatement level. As before, it seems reasonable to assume that each party will accept a treaty that guarantees it a net benefit no smaller than in the non-cooperative outcome (in which case the United States chooses the globally optimal level of abatement). As a consequence of the United States commitment, all proposals appear relatively more attractive to it and relatively less attractive to the former Soviet Union and China; the incentives these have to "free ride" have increased.

Comparing the net benefits in table 10 with those discussed already in tables 8 and 9, we see that negotiations are not helped by the unilateral commitment. The uniform percentage abatement rule is now not only unacceptable to China, but also to the former Soviet Union. All the other allocation rules that were not acceptable before are still not acceptable. The one rule that was acceptable before (the weighted average rule with Δ = 0.03 for the High Case) is still acceptable. Hence, the unilateral United States moral commitment does not alter the qualitative nature of our findings.[10]

14. The "Kantian" allocation rule

An alternative, and intellectually more appealing, rule suggested in the literature (see, for example, Laffont, 1975, and Harsanyi, 1980) is the "Kantian" rule. This rule requires each country to choose an abatement level that is at least as large as the uniform abatement level it would like all countries to undertake.

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8 Alternatively, it might be supposed that countries have altruistic preferences. However, modelling altruism is difficult. Suppose it is assumed that a country's well-being depends partly on its own net benefits and partly on the net benefits of other countries. Then the net benefits received by any one country become a public good, just as abatement does. If Country A undertakes greater abatement, Country B benefits not only because its environment is improved but also because global net benefits have increased. Hence, Country B has an incentive to abate less than before, even though (or, rather, because) it has altruistic preferences. Margolis (1982) suggests a way around this problem by distinguishing between a country's self-interest and its concern for the welfare of the whole family of nations (group interest). Resources are allocated between these two concerns according to some rule, and the utility associated with each concern is then maximized. Modelling altruism this way raises two difficulties. The first is deciding how to allocate resources to self-interest versus group interest. The other is that group interest is likely to encompass much more than just global warming. If Country A abates more of its pollution, B will abate less because of its self-interest ***and*** because the welfare of group interest would require that B allocate more resources to some other component of group interest, like human rights or population policy.

9 See Barrett (1991d) for an analysis of the "fair" distribution of net benefits under the full cooperative outcome.

10 Related to this finding, Hoel (1991) shows that "unselfish" unilateral actions that are not contingent on reaching agreement may actually compromise negotiations and lead, ultimately, to ***greater*** total emissions than would have occurred had the country behaved "selfishly".

Table 10

BASE CASE AND HIGH CASE NON-COOPERATIVE OUTCOMES ASSUMING A MORAL COMMITMENT BY THE UNITED STATES [a]

	United States	*Soviet Union*	*China*	*Total*	*Global*
Base Case [b]					
Percentage abatement	2.58	0.39	0.05	1.28	0.65
Net benefits (millions of dollars)	-44.9	39.7	5.6	0.4	155.9
High Case [b]					
Percentage abatement	20.99	3.42	0.46	10.52	5.32
Net benefits (millions of dollars)	-2,904.9	2,924.7	410.3	430.1	11,933.0

Source: Calculations by the author.

a Assuming the United States sets its own marginal cost of abatement equal to the global marginal benefit of abatement ($7.33 per ton in the Base Case and $66 per ton in the High Case). The former Soviet Union and China choose abatement at the point where their own marginal cost equals their own marginal benefit.

b Assuming ***no*** abatement undertaken by countries other than the United States, the former Soviet Union and China. The actual non-cooperative outcome ***will*** involve some abatement by other countries, so the net benefit figures shown are biased downwards.

The outcome of employing this rule is shown at the end of tables 8 and 9. We know each country's preferred choice for uniform abatement from the earlier analysis. For the Base Case, China would prefer a uniform abatement level of 0.24 per cent, the former Soviet Union 1.12 per cent, and the United States 1.67 per cent. If they each undertake these abatement levels, then we obtain the outcome shown in table 8. Total net benefits exactly equal the total under the limited co-operative outcome and, what is more, the outcome is acceptable to all three parties. The Kantian rule out-performs all the others. Indeed, it is even superior to the limited co-operative outcome in so far as that outcome is not acceptable to all three parties.[11]

The Kantian rule does not quite match the limited cooperative outcome in the High Case, but comes close. Total net benefits almost equal the total under the limited cooperative outcome, and the mechanism is acceptable to all three parties. As before, the Kantian rule works better than any of the other rules, including the weighted average rule.

This finding is particularly interesting. If countries actually believed in the moral correctness of the Kantian rule, it would not matter to them whether, choosing their Kantian abatement levels, their net benefits were higher or lower than in the non-cooperative outcome. However, it so happens that, in choosing their Kantian abatement levels, countries ***are*** better off compared with the non-cooperative outcome. This means that the Kantian rule can be seen to have virtue ***either*** because of its ethical merits ***or*** because of its attraction as a focal point. This rule performs well because it allocates TCEEs non-uniformly and because the allocation is based partly on individual country preferences.[12]

15. Sensitivity

Given the uncertainty that surrounds point estimates of benefits and costs, and the shapes of the marginal benefit and cost curves, it is important to know whether the results reported here are robust, or whether these results might change if the assumptions

11 Total net benefits are the same as in the limited cooperative outcome because of rounding.

12 This rule is similar in effect to the suggestion by Burtraw and Toman (1991) that the allocation of TCEEs should reflect each country's "outside options".

regarding the benefit and cost functions were changed.

Previous analysis by Barrett (1991c) suggests that one main result - that uniform allocation methodologies will not be acceptable to all three main country groups - is robust. Assuming that marginal benefits are not constant but decrease with the level of global abatement, and that marginal benefits and costs are linear, changes in the slopes of these functions do not alter the acceptability of the uniform allocation methodologies. Simulation shows that agreement cannot be reached between the United States, the other OECD countries and the former Soviet Union; between the OECD, China and Brazil; or between the former Soviet Union, China and Brazil. The reason is that these uniform methodologies polarize the negotiations.

Negotiations involving the OECD countries alone, however, are sensitive to the assumptions regarding the nature of the cost and benefit functions. Barrett (1991c) shows that if the slope of the marginal cost curve is high relative to the (absolute value of the) slope of the marginal abatement benefit curve, then an allocation based on uniform percentage abatement would be acceptable to the OECD countries, but one based on either the uniform per capita rule or the uniform per GNP rule would not be acceptable. As the slope of the marginal cost curve declines relative to the slope of the marginal benefit curve, these other uniform rules appear more attractive in intra-OECD negotiations.

The reason an agreement of some kind can be reached by the OECD countries is that these countries do not differ very substantially in their emissions per capita or per unit of GNP. If the slope of the marginal benefit curve is high relative to the slope of the marginal cost curve, then all these instruments are acceptable. However, if the slope of the marginal abatement benefit curve is low relative to the slope of the marginal abatement cost curve, then only the instruments that do not polarize negotiations prove acceptable.

Analysis of European Community negotiations by Barrett (1991f) indicates that the results may also be sensitive to the assumption that marginal benefits are proportional to GDP. This analysis, like the one presented here, assumes that marginal benefits are constant for each country. If marginal benefits are proportional to agricultural output, rather than total output, then the acceptability of an agreement to particular countries may change; countries with a small agricultural sector may find the cooperative agreement less attractive, and countries with a large agricultural sector may find it more so.

To summarize, changes in the nature of the cost and benefit functions will yield different results, but it seems that the two main conclusions will stand. Uniform allocations serve to polarize negotiations, because countries differ widely in their initial values for emissions per capita, per GNP, etc. The "Kantian" allocation rule performs well precisely because it does not polarize negotiations; it allocates TCEEs non-uniformly, and in a way that reflects individual country preferences for abatement.

Finally, it should be emphasized again that this analysis is not intended to provide definitive results, but to inform negotiations by identifying areas where agreement may prove difficult, and suggest better mechanisms for reaching agreement.

D. Summary and conclusions

This chapter has presented an analysis of the "acceptability" of various methodologies for allocating tradeable carbon emission entitlements (TCEEs). The analysis employs empirical information on abatement costs and benefits from Nordhaus (1991), and assumes that negotiations are fundamentally driven by self-interest. Simulation analysis is carried out for the three main emitters of CO_2 - the United States, the former Soviet Union and China. An important aspect of the analysis is capturing the interdependence that exists among countries. An allocation is taken to be "acceptable" to a country if the country receives higher net benefits with that allocation than it would if an agreement were not reached. For an agreement to be reached, the associated allocation must be acceptable to all parties concerned.

We have found that of all the ***uniform*** allocation mechanisms discussed in the literature, uniform percentage abatement appears the most attractive in total. This is because this mechanism is capable of generating total net benefits that are very close to the level associated with the outcome when countries cooperate fully. The reason this mechanism appears attractive is that it departs from the status quo. The other uniform allocation mechanisms, like equal entitlements per capita, polarize negotiations by substantially favouring one party over another. However, it remains the case that uniform percentage abatement is not acceptable to China, under the assumptions employed in this chapter. The reason for this is that, under our assumptions, China would benefit less from abatement than the United States or the former Soviet Union. Hence, if countries were to abate their emissions uniformly, China would not want emissions to be abated very much. If negotiations fail, however, the United States and the former Soviet Union would unilaterally abate their emissions somewhat because they receive relatively high benefits from abatement. China would of course benefit from this unilateral abatement, but would not have to bear significant abatement costs itself. Hence, China would do better if negotiations failed.

The implication is that an agreement employing TCEEs must allocate entitlements on a non-uniform basis. However attractive allocation rules like equal emission entitlements per capita may seem as ethical principles, they result in outcomes that severely harm certain countries - so much so that these countries would find it credible to threaten to pull out of negotiations.

Matters can be improved if TCEEs are allocated according to a weighted average rule, which allocates TCEEs partly on the basis of emissions per capita and partly on that of percentage abatement. However, simulation has shown that even this rule succeeds in winning broad acceptance only when global warming damages are assumed to be high. The reason this rule has limited success is that it favours the "average" country at the expense of countries with more extreme values for emissions per capita.

An alternative approach would be to allocate TCEEs according to two different rules, each applied to a different group of countries. The two-tier allocation rule, in particular - a rule that imposes a different obligation on poor countries than on industrialized countries - was found to do better than the weighted average rule in terms of total net benefits, but was found to be unacceptable to the former Soviet Union, given the assumptions underlying our analysis. The reason is that the two-tier allocation rule favours the countries at the extremes - the United States and China in this analysis - at the expense of countries in the middle. However, it is possible that a three-tier allocation mechanism may prove even more attractive than the weighted average mechanism. Indeed, this is verified below.

We have found that matters can be improved if countries pursue self-interest subject to moral constraints. In particular, the "Kantian" allocation rule, where countries choose abatement levels at least as high as the uniform abatement level they would like all countries to observe, comes close to the outcome in which all countries cooperate. What is more, this rule was also found to make all countries better off compared with the outcome in which negotiations fail. Hence, all countries would have an interest in agreeing on an allocation based on the principles of this rule, even if they did not agree with the moral reasoning underlying it.

The reason this rule works well is that it allows obligations to vary across countries, and recognizes that some countries have a greater preference for abatement than others. The practical implication is that negotiators should consider a percentage abatement allocation rule of three tiers or more, and require greater abatement by countries that would benefit more from it. Since the OECD countries are likely to benefit most from abatement, they should bear the greater burden of emission reduction in the initial allocation of TCEEs. However, trading will reduce the cost burden of OECD countries, and the transfer of resources to the poor countries will provide these countries with an incentive to accede to the treaty and abate their emissions.

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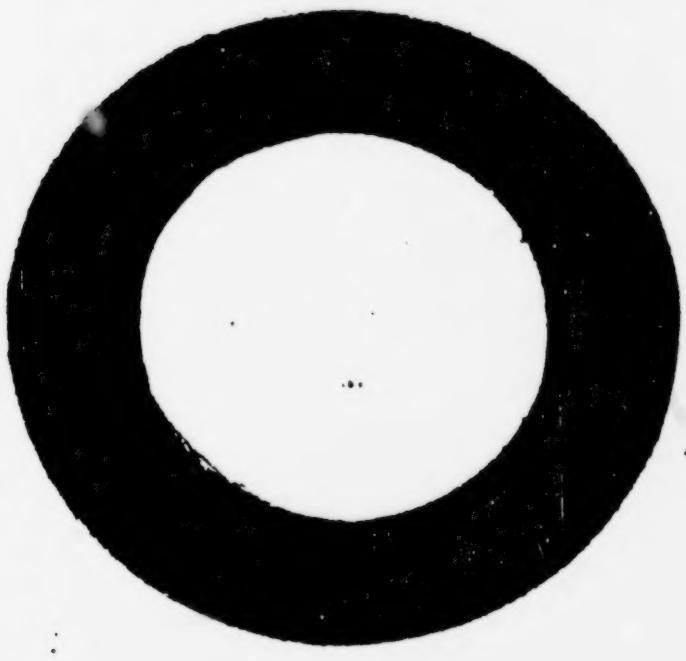

Chapter VII

TRANSFERS AND THE GAINS FROM TRADING CARBON EMISSION ENTITLEMENTS IN A GLOBAL WARMING TREATY

Scott Barrett*

Introduction

As noted in the introduction to chapter VI, the principal advantages of tradeable carbon emission entitlements (TCEEs) are that they can result in cost-effective international abatement of CO_2 emissions and transfer resources to countries less able (and perhaps also less willing) to pay for abatement. The purpose of this chapter is to provide numerical estimates of the welfare gain associated with trading - that is, the welfare gain associated with cost-effective, international abatement - and of the transfers that may result from an international agreement that employs TCEEs.

These issues are of great concern to all potential negotiating parties, but different parties will have different priorities. For the industrialized countries, the most important issue is whether the overall burden of abatement can be shared, so that costs can be kept low. For the developing countries, the most important issue is whether resources can be transferred, not only to compensate for the costs of abatement that they would otherwise not undertake, but also to enable them to acquire the technologies and know-how essential to economic growth. As shown in the last chapter, global warming is a positive sum game; if countries can reach agreement, they can all be made better off. Hence, it should be possible, in theory if not in practice, to reach an agreement that satisfies each of these concerns.

As was the case in the previous chapter, the approach taken here is analytical, and the analysis considers a very special agreement, one in which global emission reductions are achieved by means of freely tradeable carbon emission entitlements. As noted in chapter VI, it is unlikely that such an agreement will be reached from scratch. Rather, negotiations are likely to be evolutionary. Initially, a limited agreement may be reached, one that may not allow for trading or allow only for limited trading. Incrementally, as the initial agreement is renegotiated and amended, the scope for trading may be increased. The purpose of this analysis is not to predict how negotiations might evolve, or even to examine different possible evolutionary paths, but rather to explore the implications of a full-fledged TCEE agreement. As argued in the previous chapter, these implications must be understood if negotiators are to make informed decisions about the early structure of an agreement.

* London Business School, London.

In this regard, it should also be emphasized that TCEEs are not the only instruments available for achieving the twin aims of cost-effective international abatement and the international transfer of resources. Cost-effective abatement might be achieved using a coordinated carbon tax, as is currently being negotiated by the European Community. Transfers might be implemented using side payments, as is the case with the Ozone Fund set up under the amended Montreal Protocol. Alternatively, the agreement might begin by establishing national abatement obligations, and guidelines for achieving these through bilateral agreements. One industrialized country, for example, might carry out less abatement on its own soil, but transfer resources to a developing country in exchange for an agreement by the latter to abate its emissions by more than it might have done otherwise. However, one cannot estimate the cost savings or transfers associated with such "offset" trades without detailed information, for such estimates would be case-specific.

Section A below provides estimates of the consequences of trading, and relates these to the results presented in the previous chapter. Conclusions are given in the final section.

A. Estimating the consequences of trading

1. *Transfers*

How large will resource transfers be if an agreement employing TCEEs is reached? The answer clearly depends on a number of factors, including the following:

(a) Total abatement

As noted in chapter VI, if no emissions are abated in total, then no matter how TCEEs are initially allocated no transfers will result. The reason is that, if no abatement is required in total, then TCEEs are not scarce; their equilibrium price is therefore zero. All else being equal, the greater the amount of total abatement, the more scarce TCEEs become, and the greater will be the resource transfers.

(b) The initial allocation of TCEEs

In equilibrium, TCEEs will trade at a price that equates marginal abatement costs across all countries. If TCEEs are initially allocated in such a way that marginal abatement costs are already equalized, then no resources will be transferred. This was shown in the last chapter for the case of uniform percentage abatement. Assuming that the marginal costs of abating emissions by the same percentage are equal for all countries, allocating TCEEs on the basis of uniform percentage abatement results in no transfers, despite the fact that TCEEs are scarce in total. All else being equal, the closer marginal abatement costs come to the initial allocation, the smaller will be the magnitude of the transfers.

(c) The abatement costs of signatories

Given a total quantity of TCEEs, and an initial allocation of these, the magnitude of resource transfers will depend on the shape of the marginal abatement cost curves. All else being equal, the more convex the marginal abatement cost curves (that is, the more marginal abatement costs rise with the level of abatement), the smaller will be the magnitude of the transfers.[1]

Quite obviously, the magnitude of the transfers will depend on how these three factors are combined in any one case. If substantial abatement is undertaken in total, the initial allocation results in substantial variations in marginal abatement costs, and if marginal abatement costs are very convex, then transfers will be large.

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[1] For the functional form used in chapter VI, the marginal abatement cost curve is more convex the smaller the parameter α in absolute value.

However, even this analysis is over simplistic, for the agreement is also likely to affect international trade in both energy and non-energy products, and the effect of an agreement on welfare must reflect these changes as well as the magnitude of the transfers. Determination of the full effects of an agreement requires more sophisticated modelling.[2]

While a great many studies have been undertaken to estimate the costs of CO_2 abatement using carbon taxes (see Barrett, 1991a, and Darmstadter, 1991), much less research has been devoted to determining the effects of trading under an international agreement to limit CO_2 emissions. The most comprehensive study available is the recent OECD analysis (forthcoming) using the GREEN model. In presenting the OECD results, it is perhaps best to begin by comparing them with the results given in the last chapter. It should be recalled that the analysis presented in the last chapter has some empirical validity in so far as the cost and benefit relationships were taken from Nordhaus's study (1991) of the economics of climate change. The weaknesses of this analysis were noted earlier. It has been assumed that the United States, the former Soviet Union and China have the same marginal abatement cost function. Furthermore, the analysis was limited to these three countries.[3]

Table 1 compares the results obtained from chapter VI for the "Kantian" allocation of TCEEs in the High Case with the OECD results for 1995. Note that the OECD results assume that emissions are abated 9.5 per cent in total, whereas the "Kantian" case assumes that emissions are abated 10 per cent in total. The "Kantian" allocation initially requires that the United States abate its emissions 14.1 per cent, the former Soviet Union 9.6 per cent, and China 2.1 per cent, whereas the OECD case assumes uniform abatement at 9.5 per cent for all three countries. The two cases compared are similar, but not identical.

It is clear from the table that the OECD analyis finds that marginal abatement costs are higher for the United States, and lower for the other two countries compared to the analysis in chapter VI. One important reason for the difference is that the OECD uses ***existing*** energy prices as base prices for the carbon tax analysis.[4] The prices of coal, oil and natural gas are substantially lower in the former Soviet Union than in the United States. The price of coal is substantially lower in China than in the United States. Hence, all else being equal, any given tax will raise price by a greater percentage in the former Soviet Union and China than in the United States. In other words, to achieve the same percentage abatement in all three countries would require a smaller tax in the first two compared with the United States. Another factor contributing to China's low marginal abatement costs is the high share of coal in China's total fossil fuel consumption. Since the carbon content of coal is high, China can reduce its emissions substantially by switching to other fossil fuels. For countries where coal's share of total primary energy consumption is small, this opportunity for substitution is reduced.

Still, it is remarkable how similar the results are. A 10.0 per cent reduction in total emissions using the analysis of the last chapter would result in an equilibrium price for TCEEs of about $29 per ton of carbon, whereas a 9.5 per cent reduction in total emissions in the OECD analysis would correspond to an equilibrium TCEE price of $31 per ton of carbon. Even the estimates of transfers are similar. In the analysis in chapter VI, the United States can reduce its abatement obligation by 4.1 percentage points if it pays $1.6 billion. In the OECD analysis, the United States can reduce its abatement obligation by 2.7 percentage points if it pays $1.4 billion. The analysis in chapter VI indicates that if China increases its abatement by 7.9 percentage points, it can earn $1.5 billion in transfers, while the OECD analysis indicates

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2 The required modelling is more sophisticated in detail, but analysis of the acceptability of an agreement to various parties requires game-theoretic modelling, as used in chapter VI. Currently, the more detailed models cannot be used to determine whether an agreement would be acceptable to parties, or the form that an acceptable agreement might take. Rather, these models ***impose*** an agreement - a total abatement obligation, an allocation of TCEEs, and an assumption about which countries participate in the agreement and which do not - and calculate the associated consequences in terms of transfers and welfare.

3 The OECD analysis presents estimates for these countries and a few others, as we shall see later in this chapter. Unfortunately, estimates are not available for Africa and other important regions. It would, of course, be very helpful for negotiators to have such estimates, at least for representative developing countries.

4 While existing prices do vary substantially, it is not necessarily true that a global warming agreement will impose obligations based on existing prices. Hoeller and Wallin (1991) show that current interventions in energy markets mean that "implicit" carbon taxes that vary across countries already exist. It is likely that negotiators will first have to establish a benchmark from which emission reduction obligations are to be calculated. The benchmark ***may*** be existing prices and emission levels, but it is perhaps more likely that agreement will first have to be reached on appropriate energy pricing and allowed interventions in energy markets.

Table 1

COMPARISON OF "KANTIAN" ALLOCATION FROM CHAPTER VI AND OECD GREEN MODEL RESULTS

	United States	*Soviet Union*	*China*	*Total*
"Kantian" allocation - High Case				
Allocated percentage abatement	14.1	9.6	2.1	10.0
Carbon tax [a]	$42.6	$28.3	$5.9	-
Actual percentage abatement	10.0	10.0	10.0	10.0
TCEE equilibrium price [a]	$29.4	$29.4	$29.4	$29.4
Transfers [b]	-$1.6	$0.1	$1.5	0
OECD GREEN results for 1995 [c]				
Allocated percentage abatement	9.5	9.5	9.5	9.5
Carbon tax [a]	$48.5	$15.1	$9.5	-
Actual percentage abatement	6.8	14.4	18.2	9.5
TCEE equilibrium price [a]	$31.5	$31.5	$31.5	$31.5
Transfers [b]	-$1.4	$1.6	$1.8	0

Source: Chapter VI and OECD (forthcoming).
a Dollar per ton of carbon. The OECD equilibrium price is estimated from data on abatement and transfers.
b Billions of dollars.
c GREEN results are shown for some regions only. The totals correspond to global figures and not the totals for the United States, former Soviet Union and China.

that China can earn $1.8 billion in transfers if it increases its abatement by 8.7 percentage points.

A more complete analysis of the OECD results is shown in table 2, which compares the results for the year 2020 with and without trading. First consider the case without trading. One efficient means of achieving an abatement obligation is the carbon tax. Economic theory predicts that if a carbon tax of $X per ton of carbon is imposed, consumers will abate their emissions up to the point where the marginal cost of abatement just equals $X. Hence, the carbon tax that just achieves a country's abatement obligation should equal the marginal cost of abatement for that country. Since the carbon tax required to achieve the same percentage abatement (45 per cent) varies substantially, the table indicates that marginal abatement costs vary substantially - from $31 in China to $655 in Other OECD. Two reasons for this variation were explained earlier.

2. *Welfare losses and gains from trade*

Of course, these abatement levels entail total costs for these economies. The most appropriate measure of cost is the change in welfare or household real income resulting from the carbon tax needed to achieve the given abatement level.[5] Table 2 indicates that all countries suffer a loss in welfare as a consequence of the abatement policy. To know whether welfare increased or decreased in total for any country, one would also need to know the change in welfare resulting from environmental benefits (as discussed in chapter VI). The OECD analysis only considers the costs of an abatement policy, not the benefits.

The magnitude of the welfare loss could be expected to be correlated with the magnitude of the tax. However, the taxes also introduce changes in the terms of trade, and it

5 The welfare change is calculated as the equivalent variation, or the increase in income a consumer would need to receive in order to be as well off with the price change as without it. The OECD also provides estimates for changes in domestic absorption and gross domestic product.

Table 2

OECD RESULTS FOR 2020

	United States	Other OECD	Soviet Union	China	Energy DCs	India	Total
No Trading Case							
Percentage abatement	45.1	45.1	45.0	44.2	44.6	44.2	44.8
Carbon tax [a]	$421.9	$654.5	$94.0	$31.1	$534.3	$45.7	$332.0
Household real income [b] (per cent)	-1.6	-2.2	-0.1	-1.6	-14.0	-0.5	-3.5
Trading Case							
Percentage abatement	34.9	27.8	56.2	67.6	30.7	63.9	44.8
TCEE equilibrium price [a]	$166.0	$166.0	$166.0	$166.0	$166.0	$166.0	$166.0
Transfers [c]	-$31.9	-$64.1	$28.7	$75.7	-$22.6	$14.2	0
Household real income [b] (per cent)	-1.3	-1.4	1.7	5.8	-7.4	2.4	-1.5

Source: OECD (forthcoming).

Note: DCs signify developing countries throughout this study.

a Dollar per ton of carbon.

b Change from base case where no abatement is undertaken.

c Billions of dollars.

is these changes that explain the large welfare loss suffered by the Energy DCs and the small loss suffered by the former Soviet Union. For the Energy DCs, oil exports fall considerably, and this reduction in exports lowers household income. The former Soviet Union, on the other hand, experiences an improvement in the terms of trade (the price of imports falls relative to the price of exports), and hence suffers only a small loss in welfare.[6]

The effect of trading can be seen by comparing the No Trading Case with the Trading Case. As expected, the fall in household real income is less with trading; all countries gain from trade, and the total welfare loss of the abatement policy is reduced from -3.5 per cent to -1.5 per cent. Part of this gain can be explained by the fact that the equilibrium price at which TCEEs trade is about one half the average carbon tax for the No Trading Case. Countries that are net purchasers of TCEEs (the United States, Other OECD and the Energy DCs) are now able to meet their obligations at a lower total cost, and hence experience a welfare gain. Countries that are net sellers of TCEEs (the former Soviet Union, China and India) bear higher abatement costs but are more than compensated for this by the revenues from TCEE sales. In fact, all these net sellers gain in total; their welfare is improved ***compared to the case in which no policy is undertaken to improve the environment.*** Hence, even if these countries did not care about the environmental benefits, they would want to participate in the international agreement with trading. The Energy DCs gain not only from being able to reduce their carbon tax, but also because the Trading Case involves a smaller reduction in oil exports compared with the No Trading Case.

It may be helpful to compare these results with those set out in the last chapter. Table 3 presents detailed results for the "Kantian" allocation High Case with and without trading. Total costs fall from $5.3 billion in the No Trading Case to $4.3 billion in the Trading Case. Moreover, abatement costs less transfers are lower for every country in the Trading Case than abatement costs in the No Trading Case, indicating that every coun-

6 In fact, the former Soviet Union experiences a welfare ***gain*** in the years before 2020. India also experiences a gain until about 2000 (see table 4).

Table 3

DETAILED RESULTS FOR "KANTIAN" ALLOCATION - HIGH CASE

	United States	*Soviet Union*	*China*	*Total*
No Trading Case				
Percentage abatement	14.1	9.6	2.1	9.97
Benefits [a]	5,624.9	2,934.9	390.7	8,950.5
Costs [a]	3,871.3	1,394.1	41.5	5306.9
Net benefits [a]	1,753.6	1,540.8	349.2	3,643.6
Trading Case				
Percentage abatement	9.97	9.97	9.97	9.97
Benefits [a]	5,624.9	2,934.9	390.7	8,950.5
Costs [a]	1,912.5	1,494.8	937.9	4,345.2
Transfers [a]	-1,603.2	102.4	1,500.8	0
Net benefits [a]	2,109.0	1,542.5	953.7	4,605.3
Costs - Transfers [a]	3,515.7	1,392.4	-562.9	4,345.2

Source: Chapter VI.
a Millions of dollars.

try experiences a welfare gain with trading. Finally, China receives a welfare gain of $563 million, even excluding environmental benefits. This result is consistent with the OECD analysis showing that countries that sell entitlements can experience a welfare gain compared to the case where no agreement is reached, even if environmental benefits are disregarded. Note, however, that the former Soviet Union does not receive a welfare gain in table 3, but does in table 2. The reason for the difference has to do with the initial allocation. In table 2, this country sells a number of entitlements; it sells very few in table 3.

3. *The dynamics of welfare and transfers*

The analysis in chapter VI was static, and it would be useful to know how welfare and transfers may change over time. These changes, of course, depend on the rate of growth of emissions in the absence of abatement, and on how the abatement obligation changes over time.

Table 4 shows the time path for transfers and the change in household real income (compared with the base case where emissions are not abated) for the OECD analysis of trading. The simulation assumes that TCEEs are allocated in such a way that the rate of growth in emissions is reduced by two percentage points per year compared with the base case where emissions are not abated. Given the assumed rate of growth in emissions in the absence of abatement, this results in a substantial decline in OECD and the former Soviet Union emissions over time, while the developing countries increase their emissions by 20 per cent over the period 1990-2020 (China and India double their emissions in those years). This observation illustrates the point made in the last chapter that emissions are being reduced below the levels that would have been reached in the absence of abatement, but that emissions may nevertheless increase over time. These results are also consistent with the historical data shown in the last chapter, which indicate that emissions in the absence of abatement are growing much faster in the developing countries than in the industrialized countries.

Table 4 also demonstrates the claim made earlier that as the emission constraint

Table 4

TRANSFERS AND CHANGE IN WELFARE FOR OECD GREEN MODEL RESULTS

	United States	*Other OECD*	*Soviet Union*	*China*	*Energy DCs*	*India*	*Total*
1995 - 9.5 per cent abatement							
Transfers (billions of dollars)	-1.4	-1.7	1.6	1.8	-0.5	0.2	0
Household real income [a] (per cent)	0.0	0.0	1.3	1.0	-1.0	0.9	0.0
2000 - 18 per cent abatement							
Transfers (billions of dollars)	-4.2	-8.6	6.0	7.4	-1.6	1.0	0
Household real income [a] (per cent)	-0.2	-0.2	1.9	1.8	-2.3	1.2	-0.2
2005 - 25.7 per cent abatement							
Transfers (billions of dollars)	-9.8	-17.2	12.0	16.7	-4.4	2.7	0
Household real income [a] (per cent)	-0.4	-0.5	2.0	2.6	-3.6	1.4	-0.5
2010 - 32.7 per cent abatement							
Transfers (billions of dollars)	-15.4	-30.6	17.8	31.2	-8.4	5.4	0
Household real income [a] (per cent)	-0.7	-0.8	2.1	3.6	-5.0	1.7	-0.8
2020 - 44.8 per cent abatement							
Transfers (billions of dollars)	-31.9	-64.1	28.7	75.7	-22.6	14.2	0
Household real income [a] (per cent)	-1.3	-1.4	1.7	5.8	-7.4	2.4	-1.5

Source: OECD (forthcoming).

Note: As for table 2.

a Change from base case where no abatement is undertaken.

becomes tighter (all else being equal), transfers increase. For example, when emissions are abated 9.5 per cent in 1995, China receives $1.8 billion in transfers, but when emissions are abated 44.8 per cent in 2020, China earns $75.7 billion from the sale of TCEEs. The table also demonstrates that the total cost, in terms of welfare losses, increases as the level of abatement rises. However, as noted earlier, countries selling a large quantity of entitlements experience welfare gains. The gains and losses experienced by individual countries change over time.

4. Transfers and aid

To put the estimates of transfers into perspective, table 5 compares the OECD GREEN model results for transfers in 1995 with the level of official development assistance in 1988. The estimates of transfers in table 5 assume that an agreement employing TCEEs allocates entitlements on the basis that the rate of growth of each country's emissions falls two percentage points per year compared with the base case in which no abatement is undertaken, with the result that total emissions are reduced 9.5 per cent

Table 5

COMPARISON OF TRANSFERS FROM OECD GREEN MODEL AND OFFICIAL DEVELOPMENT ASSISTANCE [a]

	United States	Japan	Other OECD	China	Energy DCs	India
Official development assistance. 1988 [b]	-$10.1	-$9.1	-$28.9	$2.0	-$2.4 [c]	$2.1
1995 transfers	-$1.4	-$0.3	-$1.4	$1.8	-$0.5	$0.2
Transfers as percentage of assistance	13.9	3.3	4.8	90.0	20.8	9.5

Source: OECD (forthcoming) and World Bank (1990). tables 19 and 20.

Note: As for table 2.

a All dollar figures are in billions.

b 1988 levels.

c OPEC assistance.

compared with the base case. Table 5 indicates that the transfers associated with such an agreement are not out of proportion with current official development assistance. OECD transfers are 6.4 per cent of official development assistance. However, the estimated transfers would have the effect of almost doubling the assistance received by China.

5. *Further estimates of transfers*

Further results by Perroni and Rutherford (1991) are summarized in table 6.[7] Compared with the OECD results and the findings of chapter VI, the estimates of carbon taxes in table 6 seem high. However, it must be recognized that estimates available in the literature do vary, and can be sensitive to assumptions.[8] The initial allocation of TCEEs is also quite different compared with the OECD study. The OECD imposed similar emission reductions in percentage terms on all regions. Perroni and Rutherford impose initial abatement obligations that vary from 40 per cent in the United States to 7 per cent in the Rest of World. The former Soviet Union is a net buyer of entitlements in the Perroni and Rutherford analyis, and not a net seller as in the OECD publication (forthcoming), because it is assumed to have high marginal abatement costs relative to the United States and Other OECD. Other OECD is a net seller of TCEEs in the Perroni and Rutherford paper partly because its marginal abatement costs are not high compared with those of the United States, but mainly because its initial abatement obligation is smaller compared with the United States in the forthcoming OECD paper.

B. Conclusions

Chapter VI showed that TCEEs can initially be allocated in a way that would make an agreement employing TCEEs acceptable to countries that differ substantially in many respects. The analysis was based on a number of assumptions - all of which were made explicit - and the results may be sensitive to these assumptions. Moreover, the analysis did not consider the incentives to form coalitions, or evaluate the problem of sustaining

7 Manne and Richels (1990) have also carried out an analysis of trading TCEEs, but they do not provide detailed results.

8 Two important parameters seem to be the elasticity of interenergy substitution and autonomous energy efficiency improvement. See Burniaux *et al.* (1991) for sensitivity estimates.

Table 6

PERRONI AND RUTHERFORD ESTIMATES FOR 2020 [a]

	United States	*Other OECD*	*Soviet Union and Eastern Europe*	*China*	*Rest of World*	*Total*
No Trading						
Percentage abatement	39.7	25.7	27.3	10.3	7.1	23.3
Carbon tax	$346.8	$210.4	$336.0	$121.6	$310.3	-
Trading						
Percentage abatement	33.3	34.9	21.3	20.6	4.9	23.3
TCEE equilibrium price	$278.3	$278.3	$278.3	$278.3	$278.3	$278.3
Transfers [b]	-$40.1	$43.3	-$30.8	$38.8	-$11.2	0

Source: Perroni and Rutherford (1991).

a They assume a 20 per cent reduction in the United States, Other OECD and Soviet Union/Eastern Europe emissions and a 100 per cent increase in China and Rest of World emissions relative to 1990 emissions.

b Billions of dollars. Note that Perroni and Rutherford report the results in millions. However, their estimates for carbon emissions are actually in billions.

the agreement (deterring free riding). Finally, the allocation methodology that was shown to work best is not one that would easily be negotiated. And of course the analysis was abstract; real negotiators will have to deal with more complicated circumstances. Still, the analysis is encouraging in so far as it demonstrates (seemingly for the first time), that agreement on an allocation methodology is possible.

This chapter complements the last one by presenting estimates of the implications of negotiating a global warming treaty employing TCEEs. The results indicate that the advantages of international trading are considerable. The OECD modelling exercise indicated that a 45 per cent reduction in emissions in 2020 would reduce household real income 3.5 per cent in total without trading (given the initial allocation), but by only 1.5 per cent with trading. This amounts to more than halving the cost of achieving the global abatement goal. It should be noted here that the OECD model assumes that abatement within each region considered is achieved at minimum cost. Hence, even in the No Trading Case the OECD is essentially assuming that trading is taking place among all countries in, for example, the Other OECD region. If abatement obligations were to be allocated to individual countries, then there would be further gains from trade to be captured within each of the regions in the OECD model. In other words, it is likely that the gains from trading will be even larger than indicated by the OECD modelling results.[9]

Trading not only reduces welfare losses in total, but also the welfare losses borne by every country in the agreement. This is significant, for it means that, given any initial abatement obligation, ***all*** countries will do better with trading. For the initial allocation considered by the OECD modelling exercise, some countries - the former Soviet Union, China and India - actually received a welfare gain from the agreement. ***In other words, these countries would benefit from such an agreement even if they did not benefit at all***

9 This assumes, of course, that trading is perfect. Analysis by Barrett (1991b) of negotiations among the European Community countries indicates that uniform abatement obligations would be far more costly than a uniform carbon tax for achieving the same overall level of abatement. Since the uniform carbon tax yields the same cost-effective outcome as trading (although with different implications for individual countries), this suggests that the gains from trading within blocs of countries, such as the European Community, could be considerable. Finally, the overall gains from trading could also be achieved by an internationally coordinated carbon tax. All that is required is that the marginal abatement costs should be equal for all countries. This can be achieved either by a uniform carbon tax or by TCEEs that trade at a uniform (equilibrium) price.

from the environmental improvement associated with the agreement. Trading can therefore provide very strong incentives for these countries to want to participate in such an agreement. Depending on the perceived benefits of abatement received by the countries experiencing welfare losses, they too can be made better off. This is especially true because abatement by countries that would otherwise not reduce their emissions can be obtained more cheaply than further abatement by the countries that benefit most from abatement.

One of the lessons of the analysis in chapter VI is that, to make an agreement acceptable, there must be transfers, but these should not be too large. Without transfers, countries that do not benefit greatly from abatement will not undertake much abatement on their own. If transfers are too large, donor countries will do better acting on their own. A virtue of the OECD modelling exercise is that TCEEs are initially allocated in such a way that the transfers are not "too large." In this sense, the OECD initial allocation has a somewhat similar effect as the "Kantian" allocation. It was shown in table 5 that the OECD transfers were provided by countries that already offer development assistance, and received by countries already receiving such assistance. When emissions are abated 9.5 per cent in total (in 1995), the transfers calculated by the OECD analysis are shown to be in line with current official development assistance. The United States, for example, provides transfers that are only 14 per cent of current development assistance. China receives transfers that are 90 per cent of current assistance. These numbers suggest that the transfers associated with a carefully engineered TCEE system would be capable of assisting poor countries to abate their emissions ***and*** to develop their economies, while at the same time providing environmental benefits to the rich countries at the cost of only modest increases in current development assistance.

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Chapter VIII

IMPLEMENTATION ISSUES: A GENERAL SURVEY

Tom Tietenberg*

Introduction

Had we known long ago that human activities could have a serious impact on environmental life support systems and could deny future generations the quality of life to which our generation has become accustomed, we might have chosen a different, more sustainable, path for improving human welfare. The fact that we did not have that knowledge (and therefore did not make that choice) years ago means that current generations are faced with more difficult choices with fewer options. These choices will test the creativity of our solutions and the resilience of our social institutions.

In this chapter we shall explore some of the design issues associated with the use of a transferable entitlements system to control greenhouse gases so as to distribute the international burden of that control in a manner that is both cost effective and equitable. We begin with a consideration of the most basic design issues such as defining the roles for the various types of participants, the nature of the tradeable commodity, how the supply of entitlements could be altered, and the rules for storing and trading entitlements. We then move on to a discussion of how a workable, global transferable entitlement system might be implemented, including a consideration of special design features to deal with some of the unique potential problems that could arise in this international setting. Finally, we shall look at the special monitoring and enforcement considerations that arise in any global approach to solving environmental problems.

A. Designing a greenhouse gas trading system

1. *Key characteristics of the system*

(a) The list of controlled substances

Creating a workable transferable entitlement system must begin with agreement on the substances that will be subject to the entitlement system. What gases would be involved?

In this project we are focusing on carbon dioxide. Though a comprehensive approach incorporating all greenhouse gases allows the global warming objective to be

* Department of Economics, Colby College, Waterville, Maine.

achieved with the widest selection of options, reducing the cost of achieving any given target[1] in the harsh realities associated with implementing a workable global system of control, practical solutions dominate less practical solutions, even those which may appear superior in theory.[2] Carbon dioxide is much easier to monitor and to document than other gases such as methane.[3] Since an effective transferable entitlement system presumes a capability to calculate the effects of various control strategies on emissions, incorporating all sources of all greenhouse gases from the beginning would run the significant risk that fraudulent trades could result - trades that appear to involve equivalent reductions in greenhouse gases, but in fact do not.

Fortunately, starting with a system based on carbon dioxide does not preclude its subsequent expansion to include other greenhouse gases. The decision to incorporate other gases could be made on a case-by-case basis. Reductions in other greenhouse gases would be tradeable contingent on a demonstration that the effect of the proposed reductions on global warming would be equivalent, even considering all the associated monitoring and enforcement problems. Some sources of other greenhouse gases can already meet this test; others can not. While those meeting the test could be incorporated immediately into the system, inclusion of the others would have to await a demonstration of this capability.

(b) The entitlement

Though as a practical matter entitlements can be imposed at any stage in the life cycle of a greenhouse gas - extraction or production, consumption or emission - all other things being equal entitlements defined in terms of emissions would be preferred, as this would produce the most cost-effective outcome. With an emissions target the tendency of the market to seek the least cost means of control would be focused on reducing emissions, which, of course, is the objective.[4] But all other things are never equal, so intervening in other stages of the life cycle can become a viable, if less desirable, alternative.[5] Different entitlement systems could be established for the case of carbon dioxide emissions from fossil fuels. Requiring entitlements for fossil fuels as they are extracted, as they move through the wholesale distribution channels, as they are sold to final consumers or as the emissions are injected into the atmosphere by the combustion source are all possible points of control.

To facilitate a market in entitlement transactions the entitlement should be defined in terms of a homogeneous unit such as a ton of carbon dioxide emissions. To the extent that the entitlement involves another gas or an activity other than emission the results must be translated back into a "ton of carbon dioxide equivalent".

(c) Entitlement duration

Entitlements would be dated in annual terms - 1991, 1992, etc. - and could be used during the specified year or after, but not before. Each entitlement would allow a specific amount of emissions. Once the amount authorized by the entitlement had been emitted, the entitlement would become worthless.

(d) Global emission targets

The first step in establishing any tradeable entitlement system is to define the allowable emission levels of controlled greenhouse gases for the signatory nations. Typically these emission targets would be a

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1 For a strong presentation of this point of view see the discussion in Stewart and Wiener (1991) and United States Department of Justice (1991).

2 Richard Elliot Benedick, one of the negotiators of the Montreal Protocol, also suggests that an early insistence on a comprehensive approach could be quite counterproductive by "bogging down the negotiators and unnecessarily prolonging the entire process". See Benedick (1991b, p. 11).

3 A comprehensive treatment of this point of view is presented in Swart (1991). Victor (1991b) also suggests that a comprehensive approach is impractical, given the uncertainty of monitoring gases other than CO_2.

4 If the ratio of emissions to a produced substance is controllable, then focusing on production provides no incentives to reduce this ratio, even when that may be the preferred method of emission reduction. This problem has arisen with the Montreal Protocol, since it controls production and consumption rather than emissions. This structure provided inefficient incentives for signatory countries to test suggested technologies or to develop new technologies for the recovery and destruction of the controlled substances. See Bohm (1991).

5 In the Montreal Protocol, for example, the allowances of controlled substances are defined in terms of production and consumption rather than emissions.

function of time, recognizing both the tendencies for growth to increase emissions and the relative ease of securing reductions from new rather than old technologies. Substantial reductions are easier to secure over the long term as production technologies change than in the short run when old production technologies tend to be locked in. The emission targets would have to reflect a compromise between these two offsetting tendencies.

(e) International initial allocation

Once the allowable emission targets have been defined, the next step is to allocate these targets among the signatory countries.[6] Since other chapters will be concerned with this absolutely crucial step in the process, that discussion will not be repeated here.

The importance of making these allocations transferable cannot be overemphasized. Not only would transferability provide the basis for an international flow of funds from the industrial to the developing countries, but it could well facilitate the acceptance of lower quota limits by the industrialized nations.[7] Lower quota limits by the latter would increase the likelihood that the developing countries would participate in the agreement, since, for a given aggregate reduction, it would increase the share of future allowable emissions available to them.

(f) Domestic complementary policies

How individual signatory governments would meet their authorized emission targets would be left to them. Some might choose to use a traditional regulatory system, while others might opt for emissions charges. The effective functioning of a tradeable carbon dioxide entitlement system does not presume or require any particular choice.

(g) The private trading variant

Transferable entitlement systems could be designed in which all trades took place exclusively between governments, exclusively between private parties, or with some mix of the two. Exclusive government trading could be initiated whenever actual greenhouse gas emissions were lower than allowed by the treaty in some countries and higher than allowed in others. Tradeable entitlements could be created by a generous treaty definition of "allowable" emissions, by certified reductions in either controlled or uncontrolled greenhouse gases, or by certified increases in greenhouse gas absorption capabilities.

Governments could choose to facilitate the participation of trades by private organizations by allocating their entitlements among the various competing sources within the borders of their respective countries.[8] In theory entitlements could either be auctioned off, with the sources purchasing them from their respective governments at the market-clearing price, or distributed to each source on the basis of some allocation rule (typically historical use). Theory suggests that either approach will ultimately result in a cost-effective allocation of the control responsibility among the various polluters as long as they are all price-takers, transactions costs are low, and the entitlements are fully transferable. ***Any*** free distribution of entitlements among existing sources is compatible with cost effectiveness because the after-market in which firms can buy or sell entitlements eliminates any excess costs associated with the initial allocation. This highly significant result implies that, under the right conditions, governments can use this initial allocation of entitlements to pursue within-country distributional goals without interfering with cost effectiveness.

Both free distribution and the auction market have significant disadvantages. One of the main disadvantages of the free distribution approach is that it does not generate any revenue for the government. A major

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6 In theory the entitlements could be allocated directly to sources, skipping the allocation among nations altogether. Since a tradeable entitlement system is likely to be implemented through a treaty signed by nations, an initial allocation of entitlements to the nations is the most likely outcome of that process.

7 Acceptance of a low quota limit is likely because making the entitlements transferable opens a larger supply of emission-reducing options, thereby reducing the cost of compliance. This was the case in the negotiations over the sulphur allowance programme described in chapter IV. Bohm (forthcoming) also points out that making the entitlements transferable would allow the developing countries to negotiate and obtain larger initial quotas than they would otherwise receive.

8 It could also reserve some proportion, known typically as the growth increment, to accommodate expected future growth. This growth increment could be used to encourage the development of new employment-generating activities by providing entitlements at below-market prices.

disadvantage of the auction approach is that it raises the financial burden of the polluting firms, a significant deterrent in an increasingly competitive global market.[9]

The middle ground between these two domestic distribution approaches can be exploited to produce a workable alternative. Following the New Zealand example discussed briefly in chapter IV, governments could allocate the entitlements on a grandfathered basis, but charge an annual fee to the recipients.[10] Because this fee would be lower than the auction price, it would put less of a financial burden on the polluters. Yet the ability to collect an annual fee would make it possible for governments to derive some revenue from the system, which could be used to bolster monitoring and enforcement efforts. The ability to collect this revenue might even serve to increase the attractiveness of becoming a signatory nation.

Once completed, the initial within-country allocation of entitlements would serve as a baseline for trades of controlled substances. The entitlements would define allowable emissions of greenhouse gases; any certified reductions from that baseline would entitle the bearer to sell the excess entitlements to another party seeking to justify a higher allowable emission level than the one to which they would otherwise be entitled.

(h) Entitlement supply

Once the initial allocation has been completed, it is necessary to decide the conditions under which the supply of entitlements could be expanded. The general rule is that supply increases should not undermine the goal of global warming abatement.

One possible source of entitlement supply is provided by participants who undertake activities that absorb or destroy greenhouse gases. Currently, for example, it is possible to destroy CFCs so that they do not contribute to global warming. By allowing the certified destruction of greenhouse gases to create entitlements, the development of destruction techniques and capability would be encouraged.

Another source of entitlement expansion could come about from the development of new greenhouse gas absorption capabilities. The most obvious example is the development of new biomass plantations to sequester carbon through photosynthesis or, perhaps, saving forests scheduled for burning (thereby preventing the liberation of the sequestered carbon). Allowing these offsetting activities to create new entitlements provides a powerful inducement for them to be undertaken and therefore is a desirable objective. However, this path is not without its problems.

Generally, only offsetting activities that go beyond some prespecified baseline qualify for entitlements. The baseline establishes the "normal" or "expected" amount of planting or harvesting activity. Without the baseline it would be possible for a country, for example, to threaten to burn all its forest for the sake of acquiring valuable global warming entitlements once they could be convinced not to carry out their threat. In essence, without a properly defined baseline, incentives for counterproductive strategic behaviour are introduced.

While the within-country initial allocation of entitlements would automatically define a trading baseline for controlled substances in signatory nations, it does not define a baseline for uncontrolled greenhouse gases, for emission reductions from non-signatory nations, or from activities that could sequester greenhouse gases. Although this baseline would have to be separately defined, it could be determined on a case-by-case basis. Trades involving these activities would only be approved upon completion of the certification process (described below in section C on monitoring and enforcement). Determining the appropriate baseline would be a normal component of the certification process.

(i) Trading rules

Once the entitlement system has been defined and the initial allocation of entitlements has been completed, the rules governing entitlement trades must be determined. How are the trading ratios determined?

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9 See the support for this statement in chapter IV.

10 An alternative approach, suggested in Kägeson (1991), envisions allocating 80 per cent of the entitlements by a grandfathering approach and the remaining 20 per cent by an auction approach. His study focused on the limited objective of implementing a greenhouse gas entitlement system among the EC countries only.

For global gases, same-pollutant trades should normally take place at a one-to-one ratio.[11] For example, a one-ton emission entitlement originally held by a source in country x should, when sold, entitle the acquiring trader to a one ton emission in any country.[12]

Interpollutant trades would not generally be conducted on a one-for-one basis because the different greenhouse gases do not have the same effect on global warming. The trading ratios for interpollutant trades should reflect the relative contributions of the gases. The objective should be to assure that global warming would not be adversely affected by the trade.

Ideally, it should be possible to develop a table of equivalences, which would be published and made available to all traders in advance. Unfortunately any such table would necessarily represent a simplification of the atmospheric chemistry involved in global warming. In particular, since the reactions take place at markedly different rates, the contribution of each gas to global warming is a function of time. Reductions in some gases would have a more immediate impact than others.[13] The practical implication of these chemical reactions for policy is that the relative contribution of any two gases to global warming is not a constant. And the construction of a table of equivalences presumes that the relative contribution can be expressed as a constant.

Some proposed trades would necessarily involve some uncertainty. Suppose, for example, that the contribution of some particular greenhouse gas to global warming was not known with precision or that the capability to monitor emissions would be less than perfect (introducing the possibility that post-trade emissions would in fact be higher than expected). As an alternative to banning all such trades, one way to confront and to deal realistically with this uncertainty is to account for it in the trading ratios.

When the proposed trade involves some uncertainty about the effects, "worst case" trading ratios can be used. Suppose, for example, that the ability to monitor emissions from a new source is accurate only within 50 per cent of the actual ability. This trade could be permitted as long as twice as much reduction of this gas was required compared to a case in which monitoring was perfect. Adjusting trading ratios as a response to uncertainty offers regulators a considerable amount of discretionary flexibility.

(j) The clearing house and banking function

The global greenhouse trading system should involve a provision for a clearing house to provide a centralized location for entitlement transactions. With a clearing-house potential purchasers do not have to spend excessive amounts of time and resources searching out potential trades; they merely have to check the clearing house.

Entitlement banks should provide a safe haven for certified but unused credits. In terms of the security they offer the depositor, banked entitlements should be considered as the equivalent of entitlements in use. One problem that has arisen in the United States system of emissions trading is that some of the entitlements held in banks (which in that programme are controlled by the states) were confiscated as a means of quickly improving air quality. Confiscation, of course, had the unintended, but nevertheless very real, effect of destroying any incentive for firms to create banked credits. Regulatory authorities should not be allowed to confiscate banked credits if the proper incentives are to be maintained. Further air quality improvements can be secured while maintaining the integrity of banked entitlements, a topic discussed subsequently in this chapter.

(k) Leasing

Leasing recognizes and responds to the temporal variability in the need for entitlements, a point that has special validity in the greenhouse gas context.

As an inducement to the participation of developing countries in a comprehensive global warming agreement, the initial international allocation of entitlements is likely to grant a surplus to the developing countries. This surplus would provide an opportunity to earn revenue (from trading those surplus

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11 See the support for this statement in chapter IV.

12 The problem is complicated somewhat when the greenhouse gases also have local effects. In this case the local effects can be handled by local regulations. No trade violating a local regulation would be permitted.

13 For example, a 1 ppm concentration of methane at a point in time contributes 26 times more to global warming than an equivalent amount of CO_2, but the atmospheric lifetime of CO_2 is 10 to 20 times longer.

entitlements to the industrialized nations), and an opportunity to create an entitlement reserve to facilitate and accommodate future economic growth. Unfortunately, outright sale of the entitlements can exploit only one of these opportunities; it would provide revenue only by selling entitlements from the reserve.

Leasing provides an opportunity to fulfil both objectives simultaneously. Leased entitlements are transferred to a new owner for a fixed, prespecified period of time. (In other words a nation could lease some portion of its 1991-1994 entitlements, but retain the 1995 and subsequent entitlements.) This arrangement would work well for both the industrialized and developing countries. As restructuring the industrial system takes time, the industrialized nations could use leased entitlements to buy time while the restructuring takes place. Meanwhile the developing countries would be receiving much needed revenue from the leased entitlements. As the developing countries need more entitlements to support economic growth, they could retain the later entitlements as a guaranteed source. Leasing would facilitate the transition to a new, sustainable regime of energy use in both the developing and industrialized worlds.

2. *Special design issues*

The special circumstances associated with establishing a global version of a tradeable entitlement system for greenhouse gases give rise to some potential pitfalls. It is possible to design the system to avoid these pitfalls or to mitigate their importance.

(a) Market power

Market power can exist in entitlement markets on either the buyer's or seller's side. When traders attempt to control the price (rather than react to the market-determined price), the cost effectiveness of the system can be affected.[14]

The degree to which market power can be exercised either internationally or, if the private variant is chosen, domestically is a function of how entitlements are initially allocated. The larger the share of the initial allocation of entitlements to colluding sources , the larger is the potential deviation of ultimate control costs from the least-cost allocation. When the colluding sources are initially allocated an excess of entitlements, higher control costs can be inflicted on others by withholding some entitlements from the market. When colluding sources are initially allocated a deficit of entitlements, however, to lower prices they must necessarily bear higher control costs as the means of reducing demand for the entitlements.

As the summary in chapter IV makes clear, the evidence suggests that market power has rarely been a problem in existing uses of tradeable entitlements and is not expected to be much of a problem in a global entitlement market either. Successful cartels are difficult to establish and maintain for any commodity, and greenhouse gas entitlements would not be an exception. Successful cartelization on the seller's side depends upon an ability to capture a substantial proportion of the supply of entitlements available for sale. All other things being equal, the larger the supply that falls outside the control of the cartel, the lower the cartel's ability to wield its influence.

Because this would be a global market, the number of potential buyers and sellers is very large indeed. The market would not be thin. Since market power can only arise whenever either the buying activity or the selling activity is concentrated in the hands of a few nations, as long as the baseline (initial entitlement allocation) is defined in such a way as to create a large number of buyers and sellers, cartelization is unlikely.

Even if the initial allocation does not attract a large number of buyers and sellers, the number can be increased by other means. For example, allowing new entitlements to be created by the certified destruction of greenhouse gases and by certified increases in greenhouse gas absorption capabilities creates alternative supplies of entitlements. Allowing both international trades and the participation of private sources in these trades would also increase the number of traders.

Finally, as Grubb and Sebenius (1991) point out, the ultimate protection against the accumulation of market power is the possibility open to all nations of withdrawing from the

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14 Only if the control authority initially allocates the entitlements so that a cost-effective allocation would be achieved even in the absence of trading would the possibility of market power be completely eliminated. In this special case cost effectiveness would be achieved even in the presence of market power on either the buyer's or seller's side because no trading would take place, eliminating the possibility of exploiting any market power.

agreement. Any nation or group of nations that has been damaged by a cartelization of global warming entitlements can simply withdraw from the agreement and be unconstrained in their emissions. The right of withdrawal provides a significant check on the benefits of cartelization.

(b) Changing control needs

It is necessary to build into a global greenhouse entitlements system a process for change. Given the amount of uncertainty that currently exists with respect to global warming, change is inevitable. Yet change, if not handled carefully, has the potential to undermine the system. Tradeable entitlements systems depend on entitlement bearers having secure ownership rights to the entitlements. Insecure property rights undermine the incentive to invest in the activities that free the entitlements for sale. Can the desire to be constantly incorporating changes be made compatible with the desire to preserve sufficient security for the entitlements?

Fortunately, compatibility is possible. To the extent that a change can be anticipated it should be announced in advance. If initial entitlement allocations turn out, in retrospect, to be too high over the long run and further reductions are necessary, the schedule of further reductions should be published in advance. Uncertainty is reduced when the changes are known in advance.

Secondly, even when the ultimate changes are not known in advance, it is possible to have a stable process for incorporating them. Reviews of the aggregate emission target should be conducted on a periodic, announced schedule. The process and criteria for deciding whether a change is needed and, if so, how large it should be, ought to be made transparent to interested parties.

Finally, the process for incorporating changes should be known in advance as well. Suppose the latest scientific evidence suggests that further emission reductions are necessary. In general all entitlements, whether banked or in use to justify emissions, should be reduced proportionately or the changes should be taken out of the growth increment. Governments should ***not*** confiscate banked credits just because they are handy and not currently in use.[15] Confiscation destroys the incentive to invest in emissions reduction for the purpose of creating excess entitlements.

(c) Hoarding

In the emissions trading programme developed in the United States, fewer entitlement trades have taken place than expected. In part this is due to the fact that some sources have hoarded created credits; instead of selling them, they have retained them for possible future use. The effect has been thinner markets and fewer trades than might otherwise have been possible. Would hoarding plague a global market in greenhouse entitlements? If so, what can be done to counteract it?

The key to assessing the likelihood of hoarding in a global market is to understand the motivations that give rise to hoarding behaviour. Hoarding is a response to risk and it intensifies the very problem to which it is a response. Faced with the risk that future entitlements may not be available for sale, firms creating credits retain them to preserve their future options should they decide to expand operations.

Price risk has been another incentive for hoarding. Prices have been individually negotiated and subject to considerable variability depending on the available supply of credits. Moreover, as emissions trading transactions have taken place in local markets with few buyers and sellers, demand and supply conditions are liable to change rather quickly, and the large number of participants that is the precondition for a stable and smoothly functioning market may not be present.[16]

Is this likely to be a problem for a global market? Probably not. Its global scope would provide a large number of participants on both the buyer and seller sides of the market. Thin markets would be much less of a problem even within country trades.

Certain design features of the global system also mitigate against the occurrence of hoarding. Allowing entitlement supply to be increased by the development of greenhouse gas absorption or destruction activities provides an alternative source of entitlements. Facilitating the transboundary

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15 While this proposition may appear to be self-evident, confiscation of banked credits has in fact taken place in the United States.

16 The effect of this type of sequential trading is modeled and analysed in Atkinson and Tietenberg (1991).

flow of entitlements would also contribute to the type of vigorous market that destroys the preconditions for hoarding.

Recent developments in the markets for the sulphur allowances (the entitlements in the United States acid rain reduction programme) also provide some hope for reducing the risk associated with both the availability and price of future entitlements. A spot market for these allowances already exists. In the United States, the Chicago Board of Trade plans to establish a forward market for these allowances during 1991-1992 and subsequently even a futures market. Large brokerage firms have shown some interest in participating.

Organized markets for futures contracts, which have existed for well over 100 years, bring together those who want to minimize their risk with those who are willing to take the risk at a price.[17] An active futures market affords an opportunity for purchasers to lock in the future price and availability of entitlements, thus eliminating the need to hoard entitlements as a hedge against this risk.

The evolution of these financial markets is an important complement to the evolution of the cost-effective control of greenhouse gases. They facilitate trades by revealing prices and by reducing the risk associated with investments to reduce greenhouse gases.

Other financial devices are also being developed to facilitate the evolution of this system by reducing risk. In the United States, for example, insurance pools are currently being set up to allow the utilities to pool their risks. Since penalties associated with violating the sulphur standards are rather severe, utilities selling entitlements run the risk that some unanticipated future event (such as an equipment malfunction) could make them vulnerable to a penalty assessment. The traditional strategy to deal with this contingency is to hold more entitlements than necessary. With an insurance pool utilities would band together to share the costs of penalties levied for truly unanticipated events, providing greater security for entitlement sellers. Greater security translates into a greater willingness to sell.

Designers of the global market should, however, guard against the use of artificial (and ultimately counterproductive) strategies to strip hoarders of their entitlements. One such counterproductive strategy, for example, which has been introduced by some states in the United States, is to require banked credits to be sold or used within three years or be lost. This "use it or lose it" provision undermines the incentive to undertake emission reduction strategies that would free entitlements to be sold. The assurance of vigorous markets and the introduction of futures trading provide an effective policy response to any risk that might be associated with these markets; artificial strategies to undermine hoarding simply make the problem worse by reducing the flow of entitlements available for sale.

B. Implementing a global entitlement system

While implementing a global entitlement system to control greenhouse gases is in the narrow sense an unprecedented event, in the broader sense a large number of international precedents exist.[18] Although this is not the appropriate place to review, or even summarize, these precedents, it is important to realize that most of the individual steps involved have been undertaken before in the context of one or more international agreements.

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17 For an examination of futures markets in general see Carlton (1984).

18 Levi (1991), for example, notes the striking parallels between the requirements for a greenhouse gas entitlement system and the arrangements that grew out of the Bretton Woods Agreement of 1944. Some of the specific aspects of global warming believed to have direct parallels in the situation facing the Bretton Woods negotiators are the need: (1) to structure an agreement such that both developed and developing countries would find it in their interest to participate, (2) to balance emissions reductions with efforts to increase absorption capacity, (3) to provide technical assistance to countries too poor or too small to know the most efficient way to contribute to atmospheric improvement, (4) to monitor aggregate and individual country achievements and penalize offenders, and (5) to have the means to follow a well-defined path of net reduction in greenhouse gas emissions so as to achieve climatic stability.

1. *Initial steps*

An international system for controlling greenhouse gases must evolve slowly over time. The initial steps will necessarily be small as the parties will be hesitant to undertake large commitments.[19]

As long as the initial steps are consistent with the evolution of a cost-effective and equitable system, a slow-moving process can be an advantage rather than a disadvantage. Starting small gives both the institutions and the parties a chance to adjust and to become familiar with the system. Since most initial efforts will be precedent setting, it will take some time to work them out. Once the precedents have been established, however, the process will become smoother, quicker and better able to handle a larger number of participants, gases and entitlement trades.

Institutions will evolve along with attitudes. The clearing house and bank will be able to develop effective procedures for processing entitlement transactions. Signatory nations will become better at tracking and reporting emissions. Non-signatory nations will learn from the outside how to participate in the process and to familiarize themselves with the advantages of becoming a signatory. Maturation of the associated financial markets will lay the groundwork for reducing the transactions costs associated with trading entitlements, a process which has already been triggered by the United States sulphur allowance programme discussed in chapter IV.

The first step in implementing a transferable carbon entitlement system would require establishing carbon dioxide emission entitlements with a deadline for achievement for all signatory nations. Non-signatory nations would be treated as a group; their projected behaviour would be incorporated in the trends forecast that forms the basis for the signatory nations' allocation. Signatory nations would be free to trade these entitlements with other signatory nations subject to a certification process (described below).

Should negotiators deem it desirable to facilitate the transfer of technology to developing countries, charging an annual fee for these entitlements would supply a source of revenue to fund this programme.

A designated international organization would be responsible for receiving monitoring reports from the signatory nations, developing monitoring estimates for the non-signatory nations, preparing an annual report summarizing progress towards the treaty-specified targets (including a country-by-country assessment of compliance for signatory nations) and issuing this report to the public. This agency would also have the responsibility for: (1) providing technical assistance to all nations on available means of combating global warming (assistance to signatory nations would be subsidized), (2) maintaining an up-to-date accounting system of national obligations and achievements that would incorporate the changes occasioned by trades, and (3) establishing and running a greenhouse gas entitlement bank to store certified entitlements available for international trade.

Signatory nations would be required to report to the monitoring authority annually on the details of their compliance with treaty obligations, including a detailed estimate of the sources of emissions within their boundaries.

Though non-signatory nations would not be assigned entitlements, they could participate in the system by serving as an alternative source of carbon emission reductions. A set of rules governing the process for acquiring greenhouse gas entitlements from non-signatory nations would be established by negotiation. These rules should allow non-signatories to create entitlements for subsequent sale to signatory nations subject to a certification process. The rules should allow interpollutant trades as long as the traders can demonstrate that the potential for global warming is reduced (or at least not increased) by the trade. Leasing, as well as sales, of flow entitlements should be approved.

Approval for entitlement trades among ***signatory*** nations would hinge on a certification process run by the selling country. Certification could in principle be extended to: (1) emission reductions that are quantifiable, surplus and enforceable, (2) entitlements created by enhanced greenhouse gas absorption or by greenhouse gas destruction. Approval for entitlement trades involving ***non-signatory*** nations would be similar, with the additional requirement that the certification must secure the approval of the designated international authority as well as of the selling country.

Specific procedures for modifying the key aspects of the agreement should be

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19 For examples of proposals for initial steps, see Dudek and LeBlanc (1990) and Roland (1991).

adopted. These procedures would recognize and incorporate a better scientific understanding of atmospheric chemistry, improvements in monitoring and other changing circumstances. Specific aspects of the document subject to revision would include the aggregate emission targets and compliance deadlines, and the list of controlled substances. The document should also specify procedures for admitting new signatories.

2. *Evolving to a more complete system*

Beginning with a simple system on the understanding that it could evolve to a more complete system presumes some knowledge about the latter. Otherwise the process might well start down a path that could ultimately lead in a rather different direction. What would a more complete system look like?

The rules governing a more complicated system represent a natural evolution of the simple system by opening the agreement to more signatories, by facilitating the expansion of coverage to all greenhouse gases, and by providing the framework for tighter certification, monitoring and enforcement procedures. Principles for the evolution of this more complete system include:

- An expansion of the number of participants in the transferable carbon dioxide entitlements programme by establishing procedures for the admission of new signatory nations.

- An expansion of the list of "controlled substances" in response to deepening scientific understanding and improved monitoring technologies. The list should be subject to periodic review with specific procedures for modification announced in advance. To the extent that direct emissions monitoring is not practicable, acceptable proxies should be developed.

- The transferable entitlements programme could be expanded to include private participants. Signatory nations would be encouraged to allocate their allotment of carbon dioxide entitlements among domestic users. As it is not practical to involve small users (such as individual households) these entitlements should be allocated to the point in the distribution chain that offers the maximum opportunities for emission reduction.

- While, initially, the limited system would have to be based primarily on trust, more complete monitoring and enforcement procedures could be developed as the system evolved. The primary responsibility for enforcement of entitlement obligations imposed on individual sources would fall upon the host nation. Signatory nations should be required to adopt domestic procedures for receiving and processing complaints of violation, including complaints from public or private organizations in other signatory nations. The designated monitoring authority should provide an appeals opportunity for all complaints not resolved at the national level.

- The designated monitoring and enforcement authority would have two main sanctions at its disposal for dealing with nations that fail to comply with their treaty obligations: (1) adverse publicity, and (2) veto power over international greenhouse gas trades. Adverse publicity, a traditional international sanction, can be a powerful stimulus for compliance.[20] The veto power would be limited to specific grounds. The designated authority would merely have to determine whether or not the evidence for certifying the entitlements for sale was sufficient. A positive determination would authorize the transboundary trade. A negative determination would be accompanied, where possible, by a listing of remedial steps which, if taken, could lead to trade approval. Entitlements could be stored in the bank only after certification approval had been secured.

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20 See the examples provided in Chayes and Chayes (1991).

C. Monitoring and enforcement

Although it would be inappropriate to attempt to catalogue all the monitoring and enforcement activities that would be associated with each of the unique sources of greenhouse gases, it is essential that general monitoring and enforcement strategies be identified as well as the institutional requirements to implement them. In this section we undertake that task, paying particular attention to the relative roles for private organizations, nations and international agencies.

1. *Monitoring*

(a) National self-reporting systems

Nations that contain the individual pollution sources would have the major responsibility for monitoring and enforcing the activities of those sources. Ample precedent for this approach has been established by previous international agreements.[21]

Self-reporting of their emission levels by the sources to national enforcement agencies would be the key to the system, supplemented by cross-checks provided by other sources of data. As a standard practice in environmental regulation, self-reporting has the virtue that it is relatively inexpensive, and, when backed by the appropriate sanctions for misrepresentation, it provides remarkably accurate information.[22]

The reports should be simple, yet revealing, with respect to the compliance status of the reports. One model of this approach is provided by the discharge monitoring reports required by the United States Clean Water Act. Under that Act the National Pollutant Discharge Elimination System (NPDES) requires polluters to file with EPA discharge monitoring reports (DMRs) listing discharge levels and method of discharge.

This combination of suitably defined effluent standards coupled with monitoring reports that directly reveal the compliance status of the source has proved in the United States to be an effective enforcement vehicle not only for EPA, but for private enforcers as well. Citizens have access to the discharge monitoring reports, and the courts have generally accepted the information contained in them as proof of violations in enforcement actions brought by private parties.[23] By allowing citizens to use these reports as the basis for their claims, monitoring reports have significantly reduced the cost of both public and private enforcement activities.[24] The discharge monitoring report approach proved so successful for the control of water pollution in the United States that it was incorporated into air pollution control legislation in 1991.[25]

(b) Private monitoring

Private monitoring has also become an important check of the self-reporting system. Many bodies of water in the United States are now protected and monitored by private associations of citizens concerned about a particular body of water. One increasingly typical activity of these voluntary, privately financed associations is hiring a full-time "riverkeeper" or "harbourkeeper" to keep continuous watch on polluting activities on a particular body of water and to monitor the

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21 Since 1973, for example, the Washington Convention on International Trade in Endangered Species of Wild Fauna and Flora has established world-wide trade controls based on a permit system administered completely by the individual nations. For other examples see Sand (1991, pp. 259-261).

22 In the United States virtually all environmental statutes now make the falsification of these environmental compliance reports a criminal offence, with the responsible individual subject to personal fines and imprisonment. For further details see Segerson and Tietenberg (forthcoming).

23 See *Student Public Interest Research Group* v. *Fritzsch, Dodge and Olcott, Inc.* 579 F. Supp at 1538.

24 For an analysis of the determinants and effects of supplementing public enforcement with private enforcement as revealed by the United States experience, see Naysnerski and Tietenberg (forthcoming).

25 Section 504 of the 1991 Amendments to the Clean Air Act requires facilities to certify that they are in compliance with all applicable regulations and permit conditions. These certifications are similar to the discharge monitoring reports required under the Clean Water Act, and are also subject to sanctions for false or improper certification. See Unterberger (1991, p. 1636).

water quality itself. Successful legal actions brought against municipalities and other polluters along the Hudson River in New York State have not only been a powerful force for cleaning it up, but have established some institutional and legal precedents that are now being followed in other parts of the country.

(c) Electronic monitoring systems

Computer systems and software have now advanced to the point where it has become relatively easy to develop automated systems to aggregate and integrate all these reports, to compare them to alternative sources of data for purposes of validation, and to identify and prioritize suspected cases of noncompliance for action.[26] Both the requisite hardware and software could easily be transferred to nations that seek them.

(d) Direct vs. indirect measurement

The direct measurement of emissions is expensive, but fortunately it is also unnecessary. Because of the close link between the carbon content of the fuel and the amount of carbon dioxide emissions, monitoring the flow of fuels is not a bad proxy for monitoring emissions.[27] This is an important point because monitoring the flow of fuels is much easier than monitoring emissions. While record-keeping systems are already in place to keep track of the flow of carbon-based fuels across international borders, no counterpart exists for emissions.

(e) Record-keeping

Individual governments would also have a responsibility for assuring that all greenhouse gas entitlement trades are integrated into their emissions inventory. To ensure that their national entitlement allocations square with their emissions, all governments would at least have to be notified of trades. Following a trade of z tons from country x to country y, country y's total allocation would be increased by z and country x's reduced by z. While the total would be unaffected, the allocation of that total among the countries would have changed. When the entitlements are leased, rather than sold, the adjustments must be made when the lease begins and when it ends. To fulfil these responsibilities, each national government would have to be notified of all trades and leases affecting sources within its boundaries. Depending on the wishes of the treaty negotiators, national approval of transboundary trades may or may not be required.

(f) Certification

Prior to trading any entitlements the selling source would have to obtain certification of the entitlements. Only certified entitlements can be traded. The national government responsible for monitoring and enforcing the activities of the selling source would be responsible for the certification process. Certification criteria should be included in any global warming agreement; the United States certification process provides a possible model for this.

Three conditions would normally be necessary for certification - the emission reductions represented by the entitlements offered for trade must be enforceable, surplus[28] and quantifiable. This certification process would be required either for entitlements freed by emission reductions or for entitlements created by greenhouse gas absorption or destruction capabilities. The burden of proof is on the seller; he/she must convince the certifying authority that the conditions have been met. The certification process is necessary to prevent fraudulent trades (those which do not appear to result in a degradation or improvement of the global climate, but which in fact intensify the problem). The certification process could also be used to eliminate substitutions that are not desired outcomes of the trading process.[29]

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26 The nature of the system used to support the United States lead trading system is described in Nussbaum (1991). Kete (1991) describes in some detail the system currently being developed to support the sulphur dioxide trading system that is an integral part of the United States approach to reducing acid rain.

27 It is not a perfect proxy, however. Since combustion is the source of the carbon dioxide emissions, oil used for lubrication does not pose the same problem as oil used as a fuel. As a practical matter this can be handled by giving production facilities a credit for all oil sold for lubrication.

28 Surplus generally means reductions not otherwise required by law. For example, reductions in CFCs in fulfilment of the Montreal Protocol process would not be considered surplus, but reductions over and above those required would.

29 Some have expressed concern, for example, that a trading system would encourage the substitution of nuclear

(g) Financing

How would these monitoring and enforcement activities be financed? Private entities could pay a fee to the government for each entitlement received. This revenue could be used to finance the record-keeping and surveillance necessary to run the system. Even fees that are too low to have any significant incentive effects have the potential to generate considerable revenue.

(h) A monitoring authority

A smaller, but important monitoring role would be reserved for a newly designated international monitoring authority. One department in this organization would be earmarked to receive the individual country reports, to integrate them with estimates of emission levels for the non-signatory countries, to validate these country estimates as far as possible by cross-checking them with independent sources, and to match reported achievements with treaty obligations on a country-by-country basis. The organization would then issue an annual report containing the country-by-country compliance information, a summary of progress towards the overall global warming goals, and recommendations for the future.

While this type of *ex post* monitoring would clearly not be appropriate for all environmental problems (particularly those posing an immediate health risk), it does seem appropriate for controlling greenhouse gases. Given the rather long lags which characterize the gap between the emission of greenhouse gases and the perceived effects of the higher concentration, the delays associated with *ex post* monitoring seem inconsequential.[30]

2. Enforcement

(a) Menu of transboundary enforcement options

What works at the national level would not work or even be necessary in the international context. Oversight of the national enforcers requires a rather different approach. As Professor Louis Henkin puts it in his book *How Nations Behave*, despite some conspicuous departures, ***"almost all nations observe almost all principles of international law and almost all of their obligations almost all of the time"*** (emphasis in the original).[31]

Compliance with the norms of international law by the nation states subject to those laws is inspired less by the economic motivations that tend to drive profit-making firms than by the desire to be a part of maintaining a stable, dynamic equilibrium in international relations. This basic tendency can certainly be reinforced by an appropriately designed global warming agreement; rules universally perceived as fair are more likely to be obeyed than those rules perceived as unfair.

It can also be reinforced by instituting what Chayes and Chayes (1991, pp. 290-304) cail the principles of "accountability" and "transparency". According to these principles governments should be held accountable for their behaviour by rendering their performance transparent to scrutiny by the international community. Requiring annual reports to be submitted to the international monitoring authority and to be made public would provide the foundation for applying these principles.

Sceptics are likely to suggest that public awareness of noncompliance is not a sufficient condition for compliance. That may be true, but it is also true that the power of public awareness should not be underestimated. In the United States, for example, many toxic air pollutants had not been regulated prior to the passage of the 1990 Clean Air Act Amendments. The Emergency Planning and Community Right-to-Know Act of 1986, however, required some 20,000 plants to report annual emissions of 320 potentially carcinogenic chemicals. These reports were then made generally available. Publicized by newspapers and environmental groups, they became a rallying point for action. Even before the discussions about increasing the regulation of these substances became serious, businesses were beginning to make significant reductions in toxic emissions to counter the adverse publicity. A 39 per cent reduction in toxic emissions has already been achieved

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or hydro power for fossil fuels. Should this concern receive general support, the certification process would be the appropriate institutional arrangement to assure that these substitutions could not be the basis for trades.

30 This point is developed in Haites (1991).

31 *How Nations Behave: Law and Foreign Policy* (New York: F.A. Praeger, 1968). Cited in Chayes and Chayes (1991, p. 289).

by Monsanto. Dow Chemical plans a 50 per cent reduction by 1995; and DuPont plans a 63 per cent reduction by 1993.[32]

An alternative to taking legal action against a noncomplying party is provided by defining a complaint process to make all noncompliance transparent and to hold responsible parties accountable. One model of this approach is provided by the 1957 Rome Treaty establishing the European Economic Community.[33] Article 155 of the Treaty designated the EEC Commission as responsible for ensuring that the Treaty's provisions were applied and article 169 empowers it to initiate proceedings against any noncomplying party.

The proceedings involve four stages. In the first step "letters of formal notice" are sent by the Commission to member States believed to be in violation of an EEC environmental directive. In the second step, the member State is given the opportunity to respond to the notice, filing any information that it believes supports its position with the Commission. In the third step, the Commission issues a "reasoned opinion" confirming the infringement or dismissing the case. Finally, should noncompliance continue, the EEC has the authority to initiate legal proceedings before the European Court of Justice.

Private actions are an important component of this process. As Sand (1991, p. 272) puts it:

> What may be the most significant feature of this procedure, however, is mentioned nowhere in the treaty and evolved only gradually in the course of its implementation: more than half of the infringement proceedings initiated against member states were based not upon the commission's own monitoring of compliance but on citizen complaints- from private individuals, associations (such as Greenpeace and Friends of the Earth), or entire municipalities.

This mechanism has apparently been successful not only in encouraging complaints but in encouraging compliance as well.[34] The increasing role for public interest non-governmental organizations in the process of monitoring and enforcement in international law offers a wide range of new opportunities for enhancing the degree of compliance with international agreements.[35]

Three aspects of the Rome Treaty experience are particularly worth noting. First, the process of filing and publicizing complaints is by itself a powerful force for compliance. Secondly, affording a standing to public interest non-governmental organizations considerably strengthens a monitoring and enforcement regime based upon transparency and accountability. Finally, the process of instituting an international regime for enforcement is likely to be of an evolutionary nature. The first steps will be hesitant and will no doubt prove frustrating for those who seek to transfer the traditional national model of sanctions to an international setting. Nevertheless, experience shows that transparency and accountability can be powerful enforcement principles which can provide a foundation for action. Should further action become necessary, these initial steps will pave the way for a further strengthening of the procedures.[36]

(b) Domestic enforcement

As in the case of monitoring, the primary responsibility for enforcing the entitlements held by individual sources would fall on the countries containing the regulated source. Countries would naturally be able to chose their own set of enforcement strategies but the menu of possibilities is growing rapidly. Many conventional and some unconventional strategies exist for encouraging these sources to comply.[37]

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32 Howe (1991, p. 35).

33 Sand (1991) describes this custodial procedure as "one of the most important means of enforcing EEC environmental standards".

34 The number of complaints rose from 10 in 1982 to 460 in 1989. One complaint by a citizen of the United Kingdom against his own Government ultimately led to an investigation that resulted in infringement proceedings against seven member States. Sand (1991, p. 272).

35 For an examination of the successful roles already played by public interest non-governmental organizations in shaping, monitoring and enforcing international environmental law as well as a vision suggesting a greatly enhanced role in the future, see Sands (1989).

36 Many observers believe that harmonizing the competing claims of protecting the global environment and protecting national sovereignty will require the development of an enforcement process in stages. For one view of how this might be done in two phases see Holley (1991, pp. 82-95).

37 For a description of some of these innovative strategies and how they work in practice see the enforcement essays in Tietenberg (forthcoming).

D. Conclusions

Starting with a transferable entitlement system based solely on carbon dioxide does not preclude its subsequent expansion to include other greenhouse gases.

The decision to incorporate other gases could be made on a case-by-case basis. Reductions in other greenhouse gases would be tradeable contingent on a demonstration that the effect of the proposed reductions on global warming would be equivalent.

To facilitate a market in entitlement transactions the entitlement should be defined in terms of a homogeneous unit such as a ton of carbon dioxide emissions.

To the extent that the entitlement involves another gas or an activity other than emission, the results must be translated back into a "ton of carbon dioxide equivalent".

Entitlements would be dated in terms of years - 1994, 1995, etc. The entitlements could be used during the specified year or after, but not before.

Each entitlement would allow a specific amount of emissions. Once the amount authorized by the entitlement had been emitted, the entitlement would become worthless.

The effective functioning of a tradeable carbon dioxide entitlement system does not presume or require any particular domestic control policy.

How individual signatory governments would meet their authorized emission target would be left up to them. Some might choose to use a traditional regulatory system, while others might choose to use emission charges or transferable entitlements.

Transferable entitlement systems could be designed for all trades to take place exclusively between governments, exclusively between private parties, or with some mix of the two.

Exclusive government trading could be initiated immediately following the acceptance of specific emission targets by some group of signatory nations. Governments could subsequently choose, if they so wish, to facilitate the participation of trades by private organizations by allocating their entitlements among the various competing sources within their borders.

The supply of entitlements could be expanded beyond treaty limits as long as the expansion does not undermine the goal of global warming.

One possible source of expanded entitlement supply is provided by participants that undertake activities to destroy greenhouse gases. Another source of entitlement expansion could come about from the development and commercialization of new greenhouse gas absorption capabilities.

For global gases, same-pollutant trades should normally take place at a one-to-one ratio. Interpollutant trades would not generally be conducted on a one-for-one basis because the different greenhouse gases do not have the same effect on global warming.

The trading ratios for interpollutant trades should reflect the relative contributions of the gases. The objective should be to ensure that global warming would not be adversely affected by the trade.

Adjusting trading ratios offers regulators a considerable amount of discretionary flexibility that can be used to include even reductions characterized by a considerable amount of uncertainty.

Suppose, for example, that the contribution of some particular greenhouse gas to global warming was not known with precision or that the capability to monitor emissions would be less than perfect (introducing the possibility that post-trade emissions would in fact be higher than expected). As an alternative to banning all such trades, one way to confront and to deal realistically with this uncertainty is to account for it in the trading ratios.

When the proposed trade involves some uncertainty about the effects, "worst case" trading ratios can be used. Suppose, for example, that the ability to monitor emissions from a new source is accurate only within 50 per cent of the actual ability. This trade could be permitted as long as twice as much reduction of this gas was required compared to a case in which monitoring was perfect.

The global greenhouse trading system should involve a provision for a clearing house to provide a centralized location for entitlement transactions.

With a clearing-house potential, purchasers do not have to spend excessive amounts of time and resources searching out potential trades; they merely have to check with the clearing house.

Market power has rarely been a problem in existing uses of tradeable entitlements and is not expected to be much of a problem in a global entitlement market either.

Successful cartels are difficult to establish and maintain for any commodity, and carbon dioxide entitlements would not be an exception. Successful cartelization on the seller's side depends upon an ability to capture a substantial proportion of the supply of entitlements available for sale. All other things being equal, the larger the supply that falls outside the control of the cartel, the lower the cartel's ability to wield its influence.

A process for change should be built into a global greenhouse entitlements system.

With as much uncertainty as currently exists with respect to global warming, change is inevitable. Yet change, if not effected carefully, has the potential to undermine the system. To the extent that the change can be anticipated it should be announced in advance. So if initial entitlement allocations are too high over the long run and the ultimate desired reductions are known, the schedule of reductions should be published in advance. Uncertainty is reduced when the changes are known beforehand. Even when the ultimate changes are not known in advance, it is possible to have a stable process for incorporating those changes.

The evolution of associated financial markets for trading entitlements is an important complement to the evolution of the cost-effective control of greenhouse gases.

Mature financial markets for greenhouse gas entitlements facilitate trades by revealing prices and by lessening the risk associated with investments to reduce greenhouse gases.

An international system for controlling greenhouse gases must evolve slowly over time. The initial steps will necessarily be small as the parties will be hesitant to undertake large commitments.

As long as the initial steps are consistent with the evolution of a cost-effective and equitable system, a slow-moving process can be an advantage rather than a disadvantage. Starting small gives both the institutions and the parties a chance to adjust and to become familiar with the system. Since most initial efforts will be precedent setting, it will take some time to work them out. Once the precedents have been established, however, the process will become smoother, quicker and better able to handle larger numbers of participants, gases and entitlement trades.

Institutions will evolve along with attitudes. The clearing house and bank will be able to develop effective procedures for processing entitlement transactions. Signatory nations will become better at tracking and reporting emissions. Non-signatory nations will learn from the outside how to participate in the process and will come to appreciate the advantages of becoming a signatory. Financial exchanges will lay the groundwork for markets which reduce the transactions costs associated with trading entitlements.

An existing or new international organization would have the responsibility for receiving monitoring reports from the signatory nations, developing monitoring estimates for the non-signatory nations, preparing an annual report summarizing progress toward the treaty-specified targets (including for signatory nations a country-by-country assessment of compliance) and issuing this report to the public.

Signatory nations would be required to report to this organization annually on the details of their compliance with treaty obligations, including a detailed estimate of the sources of emissions within their boundaries.

Approval for entitlement trades among signatory nations would hinge on a certification process run by the selling country. Approval for such trades involving non-signatory nations would require the assent of the international monitoring organization.

Certification involving signatory and non-signatory nations would be handled differently. While the agreement provides a natural trading benchmark for signatory nations (defined by their allocation of entitlements), it provides no trading benchmark for the non-signatory nations. The certification procedure for non-signatories must establish that benchmark as well as fulfil the other certification requirements.

Certification could in principle be extended to: (1) emission reductions that are permanent, quantifiable, surplus and enforceable, (2) entitlements created by enhanced greenhouse gas absorption or by greenhouse gas destruction. The basis for the approval of entitlement trades involving non-signatory nations would be similar, with the additional requirement that the certification must secure the approval of the appropriate officials at the global warming authority as well as the approval of the selling country. In this way signatories could be assured that the trading benchmark was acceptable.

The monitoring organization would have two main sanctions at its disposal for dealing with those nations failing to comply with their treaty obligations: (1) adverse publicity, and (2) veto power over international greenhouse gas trades.

Adverse publicity, a traditional international sanction, can be a powerful stimulus for compliance. The veto power would be limited to specific grounds. The global warming authority would merely have to determine whether or not the evidence for certifying the entitlements for sale was sufficient. A positive determination would authorize the transboundary trade. A negative determination would be accompanied, where possible, by a listing of remedial steps which, if taken, could lead to trade approval. Entitlements could be stored in the global warming authority bank only after certification approval had been secured.

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Chapter IX

IMPLEMENTATION ISSUES: MARKET ARCHITECTURE AND THE TRADEABLE INSTRUMENT

(In Search of the Trees)

Richard L. Sandor*

Summary

This chapter discusses the evolutionary development of efficient markets, and begins the iterative process of defining the tradeable commodity and market structure for CO_2 entitlements. Lessons from other successful markets can help to guide the process of establishing an effective market. A tradeable entitlements approach for limiting global carbon dioxide emissions would lower the cost of controlling emissions, and an efficient trading mechanism would help to ensure that maximum possible cost savings are achieved.

Throughout history markets that function well have had several common features. First, the tradeable commodity was clearly defined, then the "spot" market was established, and finally forward, futures and options markets evolved. Clearly defined commodities have standardized grades, price bases, delivery mechanism and trading units. Standards help to expand mutually beneficial trading by allowing trade to focus on price negotiation. Participants in many markets world wide have developed forward and futures markets to improve trading efficiency and provide a tool for securing future transaction prices. Examples of early futures markets are rice trading in Osaka, stock trading in Amsterdam and grain trading in Chicago.

A successful spot market in CO_2 entitlements requires the issuance of a stock of standard instruments corresponding to the target emissions level. History suggests the market will work if it involves at least 10 countries accounting for at least 20 per cent of CO_2 emissions. The market might be overseen by a global environmental protection body, possibly established within the United Nations system, but experienced private sector exchanges offer efficient structures for trading. Existing exchanges provide international linkages, workable trading rules, reporting and regulatory requirements, trade clearing and financial integrity that would benefit the CO_2 entitlements market. These technologies could be shared with developing countries that may wish to develop local spot markets in CO_2 entitlements or other commodities.

* Executive Managing Director, Kidder, Peabody and Co. Incorporated; Board of Directors, Chicago Board of Trade.

The tradeable sulphur dioxide entitlements programme established under the United States Clean Air Act Amendments of 1990 is a useful prototype for the CO_2 programme. That programme delegates trading to the private sector and requires annual entitlements auctions to assist the market.

The CO_2 entitlements market will probably have several features that could lead to the evolution of futures markets. Futures markets often evolve when there is an existing, competitive spot market, a standardized product and variable prices. Futures contracts are an efficient tool for managing the risk of varying prices, and their trading is of service to everyone in that it reveals the future value of scarce commodities. Revealing the value of CO_2 entitlements will help to guide efficient emission reduction strategies and the allocation of what is perhaps the most important and truly scarce resource: the quality of our common global atmosphere.

Introduction

The drafters of and signatories to a global warming treaty, like all pioneers, have embarked on uncharted territory. What they can bring with them on their journey is knowledge and experience of the past and an adventurous and innovative spirit to explore the future.

The purpose of this chapter is to initiate the journey and to postulate the critical questions associated with its undertaking. The evolution of markets culminates in organized futures trading. The following discussion provides the background for the challenge as well as the point of departure. Futures markets are efficient, but the study of their efficiency provides little insight into the inventive process which made them efficient. Looking at the evolution of markets from this perspective is tantamount to losing sight of the trees for the forest. In order to engage in the task before us we must focus not on efficiency but on the innovative process.

New markets become efficient only after developing a subsequent organizational structure through an evolutionary process. Invention and innovation are the beginning of this evolutionary process which for purposes of this chapter we shall call "market architecture". The scope of this chapter is to apply this process of market architecture to tradeable entitlements for carbon dioxide (CO_2) abatement (i.e. the right to emit a defined level of CO_2).

Possibly one of the simplest ways to begin this project is to describe the architecture of an efficient market. Generally, organized markets serve as a unified vehicle for the allocation of capital and the transfer of price risk at the lowest cost to the users. As liquidity increases, the price differential between buyers and sellers decreases. The market becomes more efficient as we approach price equilibrium. Thus, liquidity and price efficiency are integral components if a market is to succeed. The highly efficient futures markets have evolved from the cash forward markets and are an excellent example of a highly liquid and price efficient market. Users of futures markets include both the hedger and the speculator. In this efficient market, the hedger has the most efficient means available to transfer price risk. Futures markets also attract speculators as there is usually no requirement to take delivery of the underlying physical commodity. It is this participation by a large and diverse group of participants that ensures liquidity and thus efficiency. As futures markets evolve they usually become the most liquid and efficient market for the underlying commodity, thereby serving as the best price discovery mechanism.

Some of the most liquid futures markets in the world include crude oil traded on the New York Mercantile Exchange (NYMEX); United States Treasury Bonds traded on the Chicago Board of Trade (CBOT); the Standard and Poor's 500 stock index traded on the Chicago Mercantile Exchange (CME); Eurodollar futures contracts traded on the IMM, the London International Financial Futures Exchange (LIFFE), and the Singapore International Monetary Exchange (SIMEX). Interestingly, the most efficient market in any given family of markets is often not the first market to be invented. Markets evolve and all of the above-mentioned markets evolved from less efficient futures markets. For example, the first energy futures contract was heating oil; the first stock index futures contract was the Value Line Index; the first interest rate futures contract was the GNMA or Ginnie Mae (United States Government National Mortgage Association). The first innovations were actually the catalyst for the

development of each family of futures contracts; the spark that ignited the engines of inventive activity.

These simple facts concerning the evolution of organized futures markets form the groundwork for a creative and stimulating challenge to the drafters and signatories of a global warming treaty. Instead of simply drafting a treaty providing for tradeable entitlements for CO_2 abatement with the benefit of the success of smaller market-based solutions to environmental problems, market architects must find a solution by first confronting the definition of the commodity itself. The purpose of this chapter is to begin the evolutionary process by defining a new and innovative market.

The success of the tradeable entitlement programme critically depends on the presence of an efficient mechanism for trading CO_2 entitlements, i.e. one that allows those who wish to buy and sell to do so at a low cost. The goal of the marketable entitlement approach is to lower the cost of limiting CO_2 emissions. Costs are lowered because the market encourages more emission reductions to be produced by the most efficient sources. The ability to sell easily entitlements that are freed by making large emissions cuts helps to assure that efficient sources of emissions cuts are used. Barriers to the market, such as high transactions costs or regulatory impediments, hurt the prospects for cutting the cost of lowering emissions. Organized exchanges aid the process by lowering the costs of finding a willing buyer or seller, by reducing the administrative costs of trading, and by making entitlement prices known to all. The latter offers a signal that will guide emission sources to the most cost-effective strategy for complying with emission limits.

This chapter is divided into three sections. Section A observes the workings of market architecture by presenting a concise history of the evolution of spot, forward and futures in three distinct commodity markets. This is accomplished by examining the rice trading market in Osaka during the Tokugawa era, the "ducation" share trading market during the seventeenth century in the Dutch East India Company in Amsterdam, and the grain trading market in Chicago during the nineteenth century. By examining these markets we will be providing the basis for answers to questions posed in section B. Section B examines the crucial question "What is a commodity?", specifically addressing the concept and market architecture of tradeable entitlements for CO_2 abatement. It proposes an organized method of trading the "commodity" in order to facilitate the development of efficient markets. Issues ranging from the role of organized exchanges to the coordination of international regulations and the role of developing countries as market centres will be among the topics covered. The section concludes with a presentation of the salient features of a proposed futures and options contract in tradeable entitlements for CO_2 abatement. Section C summarizes the recommendations for market architecture, and sets forth a series of recommendations addressing subsequent research that should be conducted prior to drafting a global warming treaty. It is important to emphasize at the outset that the development of market architecture is not only a science but an art. It is an iterative process that begins with specific proposals and evolves into a final structure. Our purpose is to initiate a proven process rather than fully rationalizing the initial proposals or the process.

A. The history and evolution of selected spot and futures markets

Since there are no historical precedents for the market architecture of tradeable entitlements, it is important to examine the history of select spot and futures markets to help postulate a preliminary definition of what will soon be termed a "commodity" to be traded, and the organizational structure under which CO_2 entitlement transactions should be consummated. In a seminal article entitled "Futures trading - origin, development and present economic status", often overlooked by students of futures markets, Henry Bakken[1] provides a general framework for the study of the evolution of markets. He divides

1 Bakken, Henry H. (1966). "Futures trading - Origin, development and present economic status" in *Futures Trading Seminar*, vol. III (Chicago: Board of Trade of the City of Chicago), pp. 2-5.

the evolution of market organizations into five distinct stages of development. These stages are summarized in the following manner:

- Gift giving;
- Barter;
- Spot or cash markets;
- Forward markets;
- Futures markets.

Although gift giving and barter are integral as well as interesting stages in market development, for the purposes of this research our efforts will be concentrated on the analysis of spot, forward and futures markets. These markets will provide the greatest insight into market architecture for tradeable entitlements.

Active markets with specific rules and regulations can be traced to Egypt, China and India as far back in history as 1200 B.C.[2] Organized markets also existed in ancient Rome. They were termed "fora vendalie" and specialized in specific commodities. There is limited evidence of organized markets from the fall of the Holy Roman Empire to the end of the Dark Ages. However, from the twelfth to the fourteenth centuries a series of fairs emerged throughout continental Europe. The most famous of the medieval European fairs was held in Champaign.[3] These fairs were responsible for the development of the merchant code and "Fair Letters", effectively the precursors to a bill of exchange. This social event, coupled with the financial inventions of the merchant code and bill of exchange, facilitated trade by defining a transaction, thereby implicitly giving meaning to a "commodity". Bakken's summary of the contractual elements of a transaction which emerged from this evolutionary process include (i) the agreement, (ii) transfer, (iii) payment, and (iv) warranty. These elements of a transaction implicitly define a commodity, and give us a specific insight into, as well as a format for, a more formal definition of a commodity. For the purposes of our analysis, a "commodity" will be defined by the following four salient features:

- Standard or grade;
- Unit of trading;
- Price basis;
- Delivery mechanism.

Bakken's elements of a transaction and the proposed salient features of a "commodity" provide a formal basis for an inquiry into whether specific historical precedents exist for this definition. After examining historical precedents in selected markets, reason and logic suggest that the definition of a commodity preceded the trading of that commodity, and such precedence was a necessary component of organized spot markets.

History further indicates that after a commodity is defined and an organized market is created, the market passes through an evolutionary process. Organized spot markets evolve into forward markets and ultimately into organized futures markets. As discussed later, the final evolutionary stage is eventually extended to include organized options markets. We now begin our review of these evolutionary stages of a market by briefly analysing three historical markets.

1. *Osaka: rice trading in the seventeenth and eighteenth centuries*

One of the earliest organized spot and futures markets began in Osaka, Japan, during the Tokugawa era. The Osaka Rice Exchange was organized in 1697. Zensaku Sano,[4] in an article entitled "Commodity Exchanges in Japan", indicates that the first type of transaction that occurred was "spot" rice in exchange for "rice tickets". These rice tickets were essentially warehouse receipts. They were issued by daimyos, temples and shrines.[5] Eventually these tickets became negotiable and appeared to be regularly bought and sold. The issuance and negotiability of these tickets thus defined the commodity. The Tokugawa shogunate (central government) was centred in Edo (Tokyo) and required the lords to spend part of their year in Edo to prevent insurgencies.[6] Forward transactions evolved as feudal lords had

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2 Kroll, Stanley and Irwin Shishko, *The Commodity Futures Guide* (New York: Harper and Row, 1973).

3 Bakken, Henry H., *op. cit.*, pp. 5-7.

4 Sano, Zensaku and Iura, Sentaro (1931), "Commodity Exchanges in Japan", in *Organized Commodity Markets, The Annals* (American Academy of Political and Social Science), p. 223.

5 Bakken, Henry H., *op. cit.*, pp. 8-10.

6 *Ibid.*, p. 8.

to raise cash to meet their obligations and keep up appearances. These forward transactions were termed "book transactions". They were legalized in 1730 and marked the beginning of an era of organized futures markets in Japan. The futures market was characterized by standardized contracts for standardized time periods. The basic grade for a contract was determined by the traders' majority vote. Each contract had four possible grades.[7] Sano's article suggests that options were also a component of the evolution of the organized market although no specific information on the timing of these markets was provided.[8]

This historical overview makes it easier to understand the continuous process necessary for an efficient market. In this instance, a "rice commodity" was "created". After the commodity was defined, an organized spot market was able to flourish with the documents of title initially being a rice ticket. Forward transactions began occurring and eventually evolved into organized futures markets. Academicians and professionals in studying these markets continually emphasize the role of an organized spot market as a vehicle for efficient transactions and a necessary step in the evolutionary process.

2. *Amsterdam: equity trading in the seventeenth century*

The world's earliest organized stock market appeared in 1602 when the six local "chambers" for East Indian Trade were joined together into the Dutch East India Company.[9] The rights derived from the initial payment by investors were actually participations in the shipping business. These were termed "shares", and in 1606 trading was facilitated by the fact that these shares could legally be transferred from one individual to another after the primary purchase. Trading began very actively only days after the shares were issued. The issuance of the shares coupled with the transference of ownership or negotiability created the "commodity". Short selling was legally forbidden, but by 1610 it was possible for bona fide owners of the shares to enter into futures type transactions. Short selling continued, and through a process known as "prolongation" both legal and illegal shorts could be rolled forward to a new date. This technique is widespread in modern futures markets and is termed "spreading". In Joseph de la Vega's[10] *Confusion de Confusiones* published in 1688, he describes the types of transactions that occurred in the seventeenth century at the Amsterdam Stock Exchange. They include:

- Sale and purchase of stock against the payment of cash;
- Margining of the purchase of stock;
- Future sales with the ability to rollover the obligations;
- Option contracts.

Trading in "ducation" shares evidences the formation of organized futures trading. The "ducation" shares were highly leveraged, being priced at 10 per cent of the value of the original shares.[11] They were "cash settled" at various discrete time periods and essentially seem to parallel modern stock index futures trading.

This first organized equity market in the world appears to have contained all the elements associated with the definition of a "commodity" and with the creation of shares. Once the commodity was created, the salient features of the transaction appeared almost simultaneously, creating a spot market. The spot market was followed by forward transactions, which can be thought of as futures through the trading in "ducation" shares. It is interesting to note that option contracts were also a part of the exchange's market architecture.

3. *Chicago: wheat trading in the nineteenth century*

The appearance of organized grain trading in North America substantially followed the same historical patterns of evolving markets in both Europe and Asia. Although grain trading existed in places like Buffalo,

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7 *Ibid.*, p. 11.

8 Sano, Zensaku, *op. cit.*, pp. 228-229.

9 de la Vega, Joseph, *Confusion de Confusiones*, 1688 (Publication Number 13 of the Kress Library of Business and Economics) (Cambridge, MA: Harvard University Printing Office, 1957).

10 *Idem.*

11 *Idem.*

New York, prior to the opening of the Erie Canal, Chicago nevertheless flourished as a result of the development of extensive farming and infrastructures required to feed the population centres of the east.

The Chicago Board of Trade was founded in 1848 as a spot market for grain. A variety of different grading systems and warehouse receipts existed in Chicago at this time. In 1857, the Chicago Board of Trade established standard grades for grain. These standard grades coupled with the warehouse receipts and the associated transactions defined the "commodity". The highly developed spot market was followed by a growth in forward contracts as well as in "to arrive" contracts which were a form of forward contracts. Although some debate exists on which of the latter two evolved into organized futures trading, it is clear that the exchange first established rules for futures trading in 1865. Furthermore, the standards set by the Chicago Board of Trade for grain eventually became those adopted by the United States Department of Agriculture. The warehouse receipts were further standardized through a series of both state and federal laws. This allowed the warehouse receipts to be used as collateral for bank credit, as is indicated in other historical records in Europe and possibly Asia. The final development of organized trading occurred with the development of "privileges", which were essentially options (i.e. "puts", which are the right to sell or take a short position on a commodity, and "calls", which are the right to buy or take a long position on a commodity).

In summary, by reviewing these historical patterns we have observed how the emerging market architecture in Chicago paralleled developments in Osaka and Amsterdam, creating an efficient mechanism for trade in these markets. First, the "commodity" was defined. This was followed by the development of a highly organized spot market, later evolving into a forward and then a futures and options market.

These insights provided by trading of rice in Osaka, "ducation" shares in the Dutch East India Company, and wheat in Chicago can be drawn from a historical analysis of numerous other commodities ranging from cotton in New York and Liverpool to butter and eggs in Chicago. From the limited evidence provided here as well as the extensive evidence available in the literature, we take the liberty of inferring that the following four stages exist in the process of developing an efficient market:

- Defining the "commodity";
- Establishing an organized spot market;
- Establishing a futures market;
- Establishing an options market.

We can now attempt to apply these stages to create a new commodity in tradeable CO_2 entitlements.

B. Creation of a commodity: tradeable carbon emission entitlements

1. Definition of the commodity

By the beginning of the twentieth century the definition of a commodity from which a spot market could evolve into a futures market was widely accepted: it consisted of a standardized bulk ("primary" agricultural or metal) storable commodity. The latter part of the twentieth century witnessed a significant broadening in the definition of a commodity. The success of commodities such as soybean oil, soybean meal and frozen concentrated orange juice suggested the elimination of "primary" from the definition of commodity. The success of futures markets in live cattle and hogs eliminated the necessity for storability. Currencies further expanded the definition of a commodity to a medium of exchange and eliminated the concept of bulk. The single most important change came with the birth of interest rate futures. Commodities expanded to include financial instruments. Finally, the birth of futures in stock indices with the Kansas City Value Line Index further expanded the definition of a commodity.

We are now at another watershed in the definition of a commodity. The Chicago Board of Trade recently sought approval from the Commodity Futures Trading Commission for a futures market in the tradeable allowances of sulphur dioxide (SO_2). These allowances were created by the United States Congress through the legislature and passage of Title IV of the Clean Air Act Amendments of 1990 (Clean Air Act).[12] This was a first attempt at establishing organized markets in trading of pollution "property rights". Interestingly, there is some question regarding the status of these allowances as property rights. Section 403(f) of the Clean Air Act specifically states that an allowance does not constitute a property right. However, the House Energy and Commerce Committee Report of 17 May 1990 states that allowances should be considered "utility assets and as such subject to the jurisdiction and regulation of State (and sometimes Federal) regulatory authorities". This implies that allowances should at least be considered "quasi-property". Moreover, the final legislation distinguishes between allowances and the operating permit programme of the Act. A careful study should be made of what constitutes a property by international standards in relation to the Act when drafting a global warming treaty, since, if allowances are not treated as property, free market trading would abruptly halt. Drafters of such a treaty should therefore make a thorough study of the Clean Air Act in its entirety, gleaning knowledge from both its acclaimed provisions as well as its interpretational uncertainties.

Experience in the United States with marketable offset or permit (entitlement) markets has been limited, but the lessons are valuable. The air pollution programmes that allowed existing emission sources to expand production facilities only if they reduced emissions elsewhere in the plant, or paid another plant to cut emissions, had limited effectiveness. This was due in large part to restrictions on trading and extensive administrative burdens in conducting trades. Perhaps the most successful "offsets" programme was the one used in the phase-out of lead in gasoline. Gasoline refiners who lowered lead content below the mandated target levels were allowed to sell "credits" to refiners who wished to use greater amounts of lead in their gasoline. This flexibility was widely exploited, significant trading occurred, and in the aggregate refiners obtained considerable cost savings through the flexible programme. In the case of lead content, the "property" right was clearly defined, trading was unrestricted and government approval of trades was not required.

It is extraordinarily crucial to minimize "improvements" or "novelties" during the inventive and innovative process because innovation itself is such a bold move. The Clean Air Act will be particularly useful in helping to minimize the confusion often occurring during the initial stages of the inventive and innovative process. It can effectively be used as a prototype in the drafting of a global warming treaty providing for the creation of tradeable CO_2 entitlements in spot and futures markets.

In addition to using the Act as a prototype and taking advantage of the knowledge acquired in its creation, a new market should draw heavily on existing pools of human capital. Enormous human resources currently exist among traders, economists, scientists, lawyers and members of other key professions who have analysed the provisions of the Clean Air Act and its subsequent proposed regulations. Obviously, we cannot ignore what the markets have taught us and simply install an arbitrary architecture without the direct input of knowledgeable professionals. Furthermore, we should not underestimate the amount of value that can be derived by using physical capital in the form of currently existing information systems, operations, contract markets, and software expertise.

Since CO_2 emissions are globally emitted, we suggest that the first step in accomplishing the creation of a tradeable CO_2 entitlement is to draft a global warming treaty addressing applicable concerns and delineating the basis of a tradeable CO_2 entitlement. The treaty might also provide for the creation of a United Nations agency to govern and enforce its provisions, which might be called the United Nations Global Environmental Protection Agency (UNGEPA).[13] The proposed agency would assign CO_2 property rights or "allowances" (SO_2 tradeable entitlements are called "allowances" in the Clean Air Act), to all signatories of the treaty. It might also provide for allowances to be set aside for prospective signatories. A bonus programme analogous to the SO_2 allowance programme should also be initiated. The SO_2 bonus programme al-

12 H. Rep. No. 490 (PT. 1), 101st Cong., 2d. Sess. 366 (1990 FW12).

13 This proposal need not result in the establishment of a new international organization, but could be integrated into the functions of existing, relevant United Nations bodies.

lows for bonus allocations of pollution allowances for various categories of low-SO_2 emitting entities. It also encourages desirable behaviour such as conservation through the initial distribution of entitlements.

The granting of allowances should be based on existing and/or future acceptable levels of national and global emissions. The "baseline" level of CO_2 emissions should be estimated from a prior year (e.g. 1990), based on such factors as unit-specific technology type and design, fuel type and consumption, capacity utilization, age, etc. These factors could then be correlated with "actual test-measured" emissions data to calculate baseline emission quantities. The "baseline" level of CO_2 emissions should be estimated for specific unit sources and subsequently aggregated on a country or regional basis. Once the "baseline" year and emission quantities were established, the percentage reduction target and time-frame could be determined, based on the following elements:

- Available fuel or technology modifications solutions;
- Concentration of sources and ease of regulatory enforcement;
- Definable benefits;
- Time required for orderly planning, decision-making, authorization and issuance of permits, regulatory approval and compliance, plan implementation.

The Clean Air Act, for example, sets as its primary goal the reduction of annual national SO_2 emissions by 10 million tons below 1980 levels. To achieve these reductions, the law requires a two-phase tightening of the restrictions placed on power plants fired by fossil fuels. Phase I begins in 1995 and phase II in the year 2000. By the year 2000, national SO_2 emissions are restricted to a certain extent from exceeding an 8.95 million ton cap. After 1 January 1995, certain utility units are restricted to a certain extent from exceeding enumerated tonnage levels set forth in a table incorporated in the Clean Air Act; to exceed those levels they would need to purchase emission allowances. The emission levels are based on a formula under which average heat input measured in million Btus for the "baseline" years 1985-1987 is multiplied by 2.5 pounds SO_2 per million Btus, then divided by 2000 to yield a permissible tonnage level. For phase I, the Act provides for emission allowances that would just cover utility emissions if emissions were cut to the 2.5lb/Mbtu rate. The average emission rate for phase II drops to 1.2lbs/Mbtu. Following this guideline, a good model for CO_2 emissions may be to set a "baseline" year of 1990, with a 50 per cent emission reduction target to be completed by the year 2000 or 2005 in a two-step phase, as provided for in the 1990 Clean Air Act.

Implicit in the creation of this CO_2 commodity must be a standardized method or formula set forth by the proposed agency for signatory nations to monitor these emissions. This is a necessary condition for any signatory to the treaty and critical to the success of CO_2 trading. A lack of knowledge of the existing supply, plus an inability to monitor the future supply, would make it virtually impossible to create any type of efficient market. The Clean Air Act requires the installation of Continuous Emissions Monitoring (CEM) equipment. For affected sources, actual emissions are measured and reported for:

- Sulpher dioxide (SO_2) in tons/year;
- Nitrous oxides (NO_x) in tons/year;
- Carbon dioxide (CO_2) in tons/year;
- Opacity, annual average percentage.

More than 500 and possibly 1,000 existing units will be affected, and all new units will be required to install reliable monitoring systems where the results are verifiable. Currently, new technologies are being introduced including laser-based systems.

Standardization is critical and suggests that these tradeable entitlements should be issued by a single entity as otherwise segmentation might result in credit differences. The proposed agency should therefore be the sole issuer. A format similar to the bonds issued by the United States Government National Mortgage Association could easily be followed. This would not only avoid segmentation but would also be of significant importance in the creation of credit collateralized by these allowances. This has facilitated the evolution and liquidity of many other markets.

Since the global warming treaty may not include an extensive list of nations, it is appropriate to inquire into the minimum number of signatories and their assigned allowances that would be required for an efficient market. Obviously, a market must be broad enough ultimately to attract other signatories. There is no scientific formula for determining these numbers; deciding on the most effective number of initial signatories is in fact part of the art of designing a commodity. Other successful markets ranging from Eurodollars to wheat suggest a minimum of 10 different na-

tions emitting altogether at least 20 per cent of our planet's emissions. Owing to space limitations we can only mention that these recommendations are based on some widely accepted principles and the collective experience of numerous market participants. We suggest the following as the salient features of tradeable CO_2 entitlements:

(1) ***Standard***: Deliverable allowances should be issued by the global environmental protection body. Allowances should be applicable against emissions in the current calendar year as well as in future years.

(2) ***Unit of Trading***: The contract unit should be 100 one-ton carbon dioxide entitlements.

(3) ***Price Basis***: Minimum price fluctuations should be in multiples of one dollar per ton.

(4) ***Delivery***: The global environmental protection body should maintain all CO_2 allowance tracking systems, and act as a clearing house for all allowances. Delivery should be by book entry on the records of the above-mentioned body. Delivery and issuance information should be maintained by each contract market and exchange.

2. *Establishing an organized spot market*

Having now defined our commodity, we can turn to the process of establishing a spot market. As we have seen, the historical precedents cited in this chapter as well as other evidence suggest that organized central markets can provide the most efficient mechanism for implementing spot market trading. In setting up a spot market, an obvious first question addresses the location or "form" of this market.

Initially, one might assume that a specific physical location would be best to facilitate all types of transactions and possibly be more efficient than meeting at numerous scattered locations. With the advent of electronic information systems, however, an efficient central marketplace no longer needs to be restricted to a physical space. Currently, many organized central markets have the knowledge and ability to trade both electronically as well as physically through open outcry in the marketplace.

A perfect illustration of an electronically located marketplace is the foreign exchange market. This is the world's largest commodity market and is a globally traded over-the-counter spot market. This market is traded without a central physical location through the exchange of electronic messages. The Society for Worldwide Interbank Financial Telecommunication (SWIFT) is the most important communications network for international foreign exchange transactions. It is used for efficiently transferring foreign exchange deposits and loans between thousands of banks in numerous countries throughout the world. With similar current electronic communication networks already in place throughout the world, the spot market can be centred in many locations. Any proposed marketplace, therefore, should allow for trading both electronically as well as through open outcry on the floor of member contract markets or exchanges. It is also crucial that the market for a global commodity should operate 24 hours a day because of overlapping time zones throughout the world.

Furthermore, the proposed global environmental protection body could hold an auction market facilitating the trading of the entitlement allowances. An auction can assure the availability of tradeable entitlements and will generate a price signal. These bids could be sealed-bid auctions with no minimum price or priority, starting at the highest bid and proceeding with lower bids until all available allowances are sold. Alternative auction forms, such as live open outcry, electronic auctions or live screen auctions are other possibilities. The contract market or exchange should list spot transactions on some type of electronic bulletin board announcing the current bid and offer. All transactions to buy or sell the spot commodity could be listed on the bulletin board through clearing members of the proposed agency. Purchasers and sellers of the spot commodity could then call into the contract marketplace to list bids or offers of spot transactions. The information should be updated in real time with the use of an electronic board, which would indicate the number of allowances per purchase or sale with prices indicated on the screen. Buying and selling transactions could be executed on a principal basis or agency through brokers. Monies from the purchase and sale of the allowances could be collected by domestically located clearing houses similar to the Chicago Board of Trade Clearing Corp., Euroclear and others, then transferred to the appropriate clearing house.

The proposed global environmental protection body might best facilitate trading by delegating the organization of the spot market to the private sector. This would serve a two-fold purpose. In addition to organized central markets already understanding and having the technology to implement electronic as well as open outcry trading in the CO_2 spot market, many of these markets have implemented a multitude of credit, legal and operational mechanisms vital to ensuring the financial integrity of the market. A market can never realize its full potential of efficiency if it is threatened or there is a perception of its being threatened by the danger of fraud or manipulation in the marketplace. Accordingly, checks and balances of the marketplace are often accomplished through various regulatory schemes such as self-regulation by the central markets or exchanges, governmental regulation, and designated self-regulatory agencies. Perhaps the most effective format for this market is self-regulation with international coordination.

Many organized central markets operate as self-regulating institutions. Consistent with this, these markets promulgate various rules and regulations addressing a multitude of concerns. There are rules regarding the financial integrity of each member as well as that of each member's customers; there are rules assuring the performance of the contracts as well as others outlining procedures should there be a default in performance. There are numerous trading rules and guidelines. Depending on the individual market, the rules specify various procedures ranging from the execution of an order on one's own behalf to the restriction of various types of transactions when executing an order on a customer's behalf. There are record-keeping requirements, disclosure requirements, and reporting requirements. These rules and regulations are designed to protect the integrity of the market and are usually quite effective.

Although contract markets appear to have sufficient safeguards in place to ensure the integrity of the marketplace, it is still necessary for a designated marketplace to be limited to the member nations that are regulated by their governments or a designated governmental agency. This helps to ensure that the organizational and governing structures of the self-regulated contract market or exchange provide adequate protection for the marketplace. Self-regulation in the marketplace helps to prevent potential conflicts of interest. It is also important because markets may be officially linked. The Chicago Mercantile Exchange (CME) and Singapore International Monetary Exchange (SIMEX), for example, are currently linked in trading Eurodollar futures. Such a liaison would be impossible without governmental oversight ensuring equitable trading practices and the protection of customer property and funds.

The proposed agency should further require that exchanges enter into information-sharing agreements such as those between the Commodity Futures Trading Commission and the Securities Exchange Commission in the United States, or between the Securities and Investment Board and the Securities and Futures Authority in the United Kingdom, and most recently between the Securities Exchange Commission and Commodity Futures Trading Commission, and the Commission des Operations de Bourse. These agreements are necessary in order to avoid abuses such as market manipulation or fraud. In addition, many markets may compete by trading variations of the CO_2 contract similar to the trading of the German Bund contracts on the London International Financial Futures Exchange (LIFFE) and Deutsche Terminborse. Competitive contracts and competitive markets such as the Italian notional bond traded on LIFFE and the Marché à Terme International de France (MATIF) will result in the emergence of the most efficient market. Although regulation is critical, caution must be taken to avoid duplicating levels of regulation that may add unnecessary expense.

Development of a standardized legal agreement similar to the International Swap Dealers Association, Inc. (ISDA) Master Swap Agreement would help to facilitate the development of a forward market. Standardized agreements are extremely important if free trade is to be facilitated across country borders. Such agreements would also curtail many restrictions stemming from the application of differing laws among the various countries. For example, during the past five years, ISDA has been working to have the netting provisions of the ISDA Master Swap Agreement accepted by the G-10 countries. Counterparts in one country contracting with counterparts in another country have been reluctant to enter into many transactions because of the anticipation that the netting provisions under the various countries' insolvency laws might not be applied to all contracts in the same standardized fashion. The uncertainty that payments would not be made because of the unenforceability of this provision under a country's law even though the parties contracted for such payment has severely restricted transactions. The enforceability of the netting provisions under the insolvency laws of the G-10 countries has

now been substantially clarified. ISDA has obtained legal opinions from counsel in Belgium, Canada, France, Germany, Italy, Japan, Netherlands, Sweden and the United Kingdom indicating that bilateral master agreements governing netting provisions will be upheld in each of these countries. This will lift many of the legal and credit barriers from international transactions. Standardized documents would aid in preventing similar barriers to efficiency in the CO_2 entitlement market.

It is important to emphasize that the infrastructure that will be used for tradeable CO_2 entitlements could be extended to other commodities and equities in developing countries. Economists and international organizations have often focused only on the industrial infrastructure of developing nations, neglecting the educational infrastructure that would help to protect against price movements of the countries' main commodities. In fact, the application of such marketing technology may be as important as efforts to improve agricultural productivity through irrigation projects, improved fertilization and harvesting technologies. Maximizing human capital and enhancing marketing institutions will add significant value in developing countries. It is therefore recommended that a global warming treaty should be given enabling language to ensure that developing countries are subsidized to start spot and futures markets in tradeable entitlements. This precedent already exists. The United States State Department has given a grant to the Chicago Board of Trade to assist the Budapest Commodity Exchange in developing its futures market. In conclusion, the spillover benefits associated with a CO_2 entitlement market could be of enormous value in marketing crops such as cocoa and coffee, and/or facilitating the growth of capital markets to spur economic development.

In summary, spot markets can be established world wide on existing organized spot markets, enhancing competition and efficiency in the marketplace. Current contract markets and exchanges already have an infrastructure in place to facilitate electronic and open outcry trading. Certain operations and systems will be necessary but we can rely heavily on existing technology in the marketplace and on a vast pool of human resources as well. Finally, markets in member nations need to demonstrate that they are efficiently regulated and documentation should be standardized.

3. *Establishing an organized futures market*

History suggests that, after the establishment of spot markets, forward contracts providing for delivery of a commodity in the future emerge and evolve into futures markets. At this point it seems appropriate to digress briefly into a discussion of the nature of forward transactions that may emerge after a spot market starts but prior to the establishment of an organized futures market.

In the United States, utilities are in the process of determining their compliance structure under the provisions of the Clean Air Act. Various financial institutions and brokers are developing the technology to facilitate these transactions. It is proposed that documentation be standardized similar to the master agreement format of ISDA swap agreements. Master agreements should be multifunctional, enabling one agreement to cover numerous types of transactions. These transactions would permit borrowers to achieve lower interest rates for investments in environment-enhancing equipment such as scrubbers. Furthermore, these tradeable entitlements may be linked to structured financing transactions. The sale of entitlements coupled with bond financings may minimize the capital costs associated with compliance. It can also be expected that equipment and commodity vendors may enter into numerous swap contracts with utilities in order to ensure that compliance occurs at the minimum cost. The numerous transactions that are being considered cover far too wide a range to discuss in this chapter. Nevertheless, it is important to indicate that United States forward transactions are contemplated and will probably be executed as soon as the commodity is defined.

It is now appropriate to turn our attention to the most highly evolved form of market - the organized futures markets. Although there is no historical evidence of a successful futures market in pollution property rights or in tradeable entitlements for emissions, there is every reason to believe that they lend themselves to trading in futures.

The role of a futures market is to provide a mechanism for price discovery as well as for hedging. In order to capture these benefits, economists and market practitioners

have defined a set of conditions necessary for a successful market.[14] They are:

- Homogeneity;
- Existence of a spot market;
- Competitive markets;
- Price variability;
- Inefficient hedging alternative;
- Contract design.

Homogeneity and competitive markets are ensured by the definitions in this paper. These conditions are easily satisfied if the signatories to the treaty include nations emitting altogether at least 20 per cent of our planet's emissions. If signatories include the United States, Japan or the European Community countries, provisions should be made to transfer their entitlements to the private sector in order to ensure that one country would not hold a sufficient amount to have a price congestive effect on the market. China may have a significant price effect on the tradeable entitlements. If China is an original signatory to the treaty, a successful spot and futures markets would require that 50 per cent of the tradeable entitlements instead of 20 per cent must be among the signatories to ensure homogeneity and competition. Alternatively, restrictions could be enacted to prevent any individual entity from having more tradeable entitlements than the supply of all signatories, regardless of the base year levels discussed earlier in this chapter. As regards price variability, this should be present as a result of economic activity that varies regularly. Only time will determine whether volatility will be sufficient to require hedging. An inefficient hedging alternative is not relevant at this particular time.

The remaining requirement is to develop and design a contract. As we have indicated earlier, this is an art rather than a science. For example, it took approximately 23 or more revisions before the GNMA futures contract was finalized.[15] The following recommendations on the salient features of a futures contract for tradeable carbon emission abatement entitlements are based on the relevant literature as well as on design knowledge of recently traded successful commodities:

(1) ***Trading Unit:*** The contract unit should be 100 one-ton tradeable entitlements in carbon dioxide.

(2) ***Standards:*** Deliverable allowances should be issued by the global environmental protection body and registered by relevant exchanges. Allowances should be applicable against emissions in the current calendar year and for future years.

(3) ***Price Basis:*** Minimum price fluctuations should be in multiples of one dollar per ton.

(4) ***Delivery:*** Delivery should be by book entry on the ownership records of the global environmental protection body and records of relevant exchanges.

(5) ***Trading Months:*** Trading in tradeable entitlements for carbon dioxide should be conducted in the current month and the next eleven months plus quarterly listing in the March, June, September and December cycle for two additional years.

(6) ***Trading Hours:*** Hours for trading should be 8:30 a.m. to 2:30 p.m. Greenwich Mean Time or determined locally by designated exchanges.

(7) ***Trading Limits:*** Daily trading limits should be $25.00 per allowance to $2,500 per contract. Variable limits should be set at 150 per cent of the daily trading limit. No trading limit should be in effect for the current month.

(8) ***Last Day of Trading:*** No trades in entitlements in carbon dioxide futures deliverable in the current month should be made during the last three business days of the month.

(9) ***Position Limits:*** Speculative position limits should be 2,000 contracts in the current month and 5,000 contracts overall.

It is important to emphasize that this is simply a starting point that will iterate to a final contract. For purposes of the present chapter, this particular commodity contract will follow the outline used by the Chicago Board of Trade in tradeable SO_2 entitlements.[16] It should be kept in mind that our

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14 Sandor, Richard L., "Innovation by an exchange: A case study of the development of the plywood futures contract", *Journal of Law and Economics*, April 1973, pp. 119-136.

15 Sandor, Richard L., "Chicago Board of Trade clean air futures for emissions allowance program risk management", *Financial Exchange*, vol. 10, No. 2 (Chicago Board of Trade, September-October 1991), pp. 9-10.

16 Sandor, Richard L. and Howard Sosin, "Inventive activity in futures markets: A case study of the development

purpose is to make use of as much existing technology as possible to ensure faster approval by regulatory agencies in member nations. Furthermore, the analytical and trade processing software costs of implementing this new market are minimized. Contracts will vary slightly depending on the contract market or exchange involved.

The importance of the details of contract design are illustrated by default penalties. In designing the contract, care must be taken not to be overzealous. It is often best not to specify certain provisions such as specific damage calculations in the event of a default. Oddly enough, locking a certain calculation into the contract may cause a default because it may become economically beneficial for a party to default rather than to perform on the contract. Again, much knowledge will be gained by studying the effect of these clauses in similar commodity trading markets.

4. *Establishing an organized options market*

Options contracts evolved from the forward and futures markets and mark the final stage in market evolution. Historically, options have been controversial. Commodity options trading was even prohibited in the United States after the grain markets collapsed in the 1930s. Options trading, however, has overcome its negative press and options are now considered to be integral to the successful trading of a market. The following are the salient features of an options contract:

(1) ***Trading Unit:*** One tradeable CO_2 entitlement futures contract.

(2) ***Trading Hours:*** 8:30 a.m. to 2:30 p.m. Greenwich Mean Time.

(3) ***Trading Months:*** Trading in entitlements for carbon dioxide should be conducted in the current month and the next eleven months plus quarterly listing in the March, June, September and December cycle for two additional years.

(4) ***Price Quotation:*** Prices should be quoted in dollars and cents per contract.

(5) ***Minimum Price Fluctuation:*** Minimum price fluctuations should be in multiples of $.25 per ton.

(6) ***Maximum Daily Limit:*** None.

(7) ***Last Trading Day (Expiration Day):*** Second Friday of the month prior to the delivery month of the underlying CO_2 futures contract, provided there are at least five days remaining to trade in the underlying futures contract.

(8) ***Exercise:*** By 3:30 p.m., on any day up to and including the option's expiration. "Call" buyers should acquire a long position in the underlying futures contract; "put" buyers a short position. "Call" writers should be assigned a short position in the underlying futures contract; "put" writers a long position.

(9) ***Strike price:*** Strike prices should be in increments of $10.00 per contract. At all times at least seven strike prices should be available for "puts" and "calls" on the underlying futures contracts. The middle strike price is closest to the previous day's close of the underlying futures contract. Strike price boundaries should be adjusted according to the futures price movements.

C. Market architecture: a series of recommendations

The purpose of this chapter has been to define tradeable CO_2 entitlements as a commodity, and to make recommendations as to how this commodity can be efficiently traded on a global basis. We first defined the commodity. We then recommended that existing contract markets or exchanges around the world should be free to begin local spot markets provided there was some form of oversight by the local or domestic government and certain rules and regulations were in place. Furthermore, because of the unlimited potential spillover benefits, we suggested that certain developing countries should have their marketing infrastructure developed through a grant programme.

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of the first interest rate futures market", in Manfred E. Streit (ed.), *Futures Markets: Modelling, Managing and Monitoring Futures Trading* (Cambridge, MA: Basil Blackwell, 1985): 255-272.

Many of the points made in this chapter have been preliminary but can nevertheless be rationalized by empirical evidence and economic theory. It is extraordinarily important to emphasize that these are recommendations for a starting point; a place to begin initiating the process. Subsequent research should be to iterate final definitions and contracts through the interaction of market participants in the public and private sectors. It is typical for these contracts to undergo scores of changes in the drafting stages before final definitions and contracts are adopted. However, this research phase can provide enormous educational benefits, and spreads the final authorship to numerous market participants. It is essential for the ultimate parties to a contract - both buyers and sellers - to participate in the process so that they have a direct knowledge of the equitable nature of the commodity and the associated contracts.

A study of the history of markets reveals that new types of commodities and markets emerge as a result of enormous structural economic changes. The political unification of Japan, the discovery of the new world and the westward expansion of the United States provided the background for the social and financial inventions that occurred during those times. Interest rate futures were born as a result of world-wide inflation that occurred together with changes in economic conditions following a stable period after the Second World War. We appear to be at a similar watershed with regard to defining environmental "commodities" and establishing spot and futures markets in these property rights.

Air and water are simply no longer the "free goods" that economists once assumed. They must be redefined as property rights so that they can be efficiently allocated. It is self-evident that the allocation of these scarce but vitally important resources will be a major problem of the twenty-first century and beyond. Population growth and further industrialization of the planet assure this. These simple facts make it essential for research to continue as rapidly as possible so that we can implement market solutions to the highly critical environmental problems facing us.

About the authors

- **SCOTT BARRETT** received a B.S. degree, *summa cum laude*, in Resource Economics from the University of Massachusetts at Amherst, a M.A. degree in Economics from the University of British Columbia, and a doctorate (Ph.D.) in Economics from the London School of Economics. In 1990, he was awarded the Resources for the Future Dissertation Prize in Environmental and Resource Economics.

  Dr. Barrett is now Assistant Professor of Economics at the London Business School, and a Research Director at the Centre for Social and Economic Research on the Global Environment.

  He has advised a number of international bodies on the economics of negotiating a climate change treaty, including the Organisation for Economic Co-operation and Development, the Commission of the European Communities and the United Nations.

- **MICHAEL GRUBB** received a degree in Natural Sciences from Cambridge University. He subsequently worked at the Cavendish Laboratory in Cambridge and at Imperial College in London, where his studies resulted in a wide range of publications on the planning of electricity systems and the economic prospects for renewable energy sources.

  Dr. Grubb is a Research Fellow at the Energy and Environmental Programme of the Royal Institute of International Affairs, where he has directed the Institute's international programme on climate change. His publications in this area include a report on the issues and options for negotiating an international agreement on limiting carbon dioxide emissions, and a two-volume international project entitled *Energy Policies and the Greenhouse Effect*, together with a range of journal publications on economic and political aspects of the problem. He is currently completing a study of the policy implications and impacts of emerging energy technologies.

  In addition, he is an adviser to the United Nations Environment Programme, particularly concerning economic aspects of climate change, and to other international research projects on economic and policy aspects of the problem.

- **KJELL ROLAND** holds degrees in Economics and Philosphy from the Universities of Oslo and of Tromso, respectively. In 1980 he also received a higher degree in economics (cand. oecon) from the University of Oslo.

  He has worked for six years with the Department for Economic Analysis at the Research Department, Central Bureau of Statistics, including one year as a visiting scholar at Stanford University Departments of Economics and Operations Research. He also initiated and has worked in the ECON consultancy group, Oslo, since its inception in 1986. His main fields of work are energy and environmental economics, energy modelling and macroeconomic modelling.

  In addition to lecturing, graduate supervision and research, Kjell Roland is the author of numerous publications and articles on his fields of interest.

- **ADAM ROSE** holds a B.A. degree in Economics from the University of Utah, and a M.A. degree and doctorate (Ph.D.) from Cornell University.

  Dr. Rose is Professor and Head of the Department of Mineral Economics at the Pennsylvania State University. He previously served as Professor and Chairman of the Department of Mineral Resource Economics at West Virginia University, Assistant Professor in the Department of Economics at the University of California-Riverside, and Senior Council Economist for the New York State Council of Economic Advisers.

Dr. Rose's research and teaching have been primarily in the areas of energy, environmental, and regional economics. He is currently involved in research on clean coal technologies and environmental policy, natural-resource-dependent economies, and energy and material substitution.

He is the author of various publications and has written a number of articles for such periodicals as *The Energy Journal, Annual Review of Energy, Journal of Environmental Economics and Management, Journal of Regional Science, Economic Systems Research, Resources and Energy, Energy Economics, Energy Policy, Resources Policy, Environment and Planning*, and *Journal of Energy and Development*.

Dr. Rose serves on the editorial boards of the *Journal of Regional Science* and *Resources Policy*, as well as on the advisory boards of several research units at Penn State. He is the American Economic Association Representative to the American Association for the Advancement of Science. He is also the recipient of a Woodrow Wilson Fellowship and the American Planning Association's Outstanding Program Planning Honor Award.

- **RICHARD L. SANDOR** received his B.A. degree from City University of New York, and his doctorate (Ph.D.) in Economics from the University of Minnesota.

  He is currently an Executive Managing Director at Kidder, Peabody and Co., Inc. He was formerly President and Chief Executive Officer of Indosuez International Capital Markets Corporation, affiliated with Banque Indosuez, and Chairman of Indosuez Carr Futures. Before that he held positions as Executive Vice President, Drexel Burnham Lambert, Vice President and Chief Economist of the Chicago Board of Trade, and faculty member of the School of Business Administration, University of California, Berkeley. He was also named the first Martin C. Remer Visiting Distinguished Professor of Finance in the Graduate School of Management at Northwestern University. While at the Chicago Board of Trade he earned the reputation of the "principal architect of interest rate futures markets".

  Dr. Sandor has served on numerous committees and boards, including the Chicago Board of Trade, Chicago Mercantile Exchange, Banking Research Center of Northwestern University and Columbia University Futures Center. In 1991 he was elected as a Non-Resident Director of the Chicago Board of Trade and is a member of the Financial Products Advisory Committee of the Commodity Futures Trading Commission.

- **THOMAS H. TIETENBERG** was awarded the title of "Distinguished Graduate" of the USAF Academy in 1964, and in 1971 he received a doctorate (Ph.D.) in Economics from the University of Wisconsin, Madison.

  He is currently Christian A. Johnson Distinguished Teaching Professor of Economics at Colby College, Waterville, Maine.

  Dr. Tietenberg is the author or editor of five books (including *Environmental and Natural Resource Economics*, the best selling textbook in the field, and *Emissions Trading: An Exercise in Reforming Pollution Policy*, the most widely cited book on the American experience with marketable permits) and nearly fifty articles and essays on environmental and natural resource economics. He has been writing and consulting on marketable permits approach to pollution control since 1971. Elected President of the Association of Environmental and Natural Resource Economists in 1987-88, he previously served as the Director of the Macroeconomic Impact Division in the US Federal Energy Administration. He has also served as a consultant on environmental policy to the World Bank as well as to a number of domestic and foreign organizations.

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